The Corticolous Crustose and Microfoliose Lichens of Northeastern Brazil – Diversity, Ecology, and Conservation

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Vorgelegt von

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Dedicated to my son Mauricio Luis,
and my parents, Nilton Pedro
and Maria Eugenia

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1. List of Submitted Research Articles

CÁCERES, M. E. S. (2007): **Corticolous crustose and microfoliose lichens of northeastern Brazil.**

Scheduled for publication in Libri Botanici, IHW-Verlag

Corresponding author: Dr. Gerhard Rambold (gerhard.rambold@uni-bayreuth.de)

CÁCERES, M. E. S., LÜCKING, R. & RAMBOLD, G. (2007a): **Corticolous microlichens in northeastern Brazil: Habitat differentiation between coastal Mata Atlântica, Caatinga and Brejos de Altitude.**

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Corresponding author: Dr. Gerhard Rambold (gerhard.rambold@uni-bayreuth.de)

CÁCERES, M. E. S., LÜCKING, R. & RAMBOLD, G. (2007b): **Phorophyte specificity and environmental parameters as determinants for species composition, richness and area cover in corticolous crustose lichen communities in the Atlantic rainforest of northeastern Brazil.**

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Corresponding author: Dr. Gerhard Rambold (gerhard.rambold@uni-bayreuth.de)

CÁCERES, M. E. S., LÜCKING, R. & RAMBOLD, G. (2007c): **Efficiency of sampling methods for accurate estimation of species richness: corticolous microlichens in the atlantic rainforest of northeastern Brazil.**

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Extended Summary

2.1. Introduction

2.1.1. General Introduction

For a long time lichens were considered to represent autonomous organisms, until DE BARY (1866) and SCHWENDENER (1867) discovered their dual nature: a symbiosis between a fungal and an 'algal' component. The fungal component or mycobiont is in most cases (> 99%) represented by an ascomycete, while less than one percent of lichenized fungi are basidiomycetes (KIRK *et al.* 2001). The 'algal' component or photobiont either belongs to the green algae (mostly Trebouxiophyceae or Trentepohliophyceae) or the cyanobacteria or, in rare cases, to the Heterokontophyta (TSCHERMAK-WOESS 1988; SANDERS *et al.* 2004). About 15,000 species of lichenized fungi are currently accepted, but recent inventories in the tropics suggest that total number is closer to 20,000, which makes about half of all Ascomycota.

The most important character separating lichenized fungi from their non-lichenized relatives is the advent of the lichen thallus, believed to have derived from generative tissue originally covering the ascomata and at one point including photobiont cells. Many lichens have a crustose thallus closely adnate to the substrate and lacking elaborated structures. Foliose thalli are believed to be more competitive and apparently have evolved independently in different lineages, such as the Parmeliaceae, Physciaceae, Teloschistaceae, Peltigerineae, Umbilicariaceae, and Verrucariaceae (*Dermatocarpon*). Fruticose thalli have a much increased surface to biomass ratio and often occur in habitats where precipitation occurs mainly as vapor (clouds, mist, and fog). Typical representatives include many Parmeliaceae (*Usnea*, *Alectoria*, *Bryoria*), Teloschistaceae (*Teloschistes*), Bacidiaceae (*Ramalina*), Roccellaceae (*Roccella*, *Dendrographa*), and Coccocarpiaceae. Fruticose thalli may have evolved either from crustose (Bacidiaceae, Roccellaceae) or from foliose ancestors (Parmeliaceae, Teloschistaceae, Coccocarpiaceae). Some terricolous and saxicolous fruticose lichens, such as Cladoniaceae and Stereocaulaceae, seem to have developed their fruticose thallus initially as an adaptation to elevate their ascomata above ground.

Because of their large thalli, foliose and fruticose lichens are termed 'macrolichens', while crustose and some microfoliose representatives are called 'microlichens'. Macrolichens are investing more energy into the formation of their thallus and hence are usually restricted

to habitats with certain favorable climatic conditions, while microlichens are less dependent on microclimate and also occur in habitats where most macrolichens cannot establish. This includes the tropical lowland rainforests, whose lichen communities are almost exclusively composed of crustose microlichens (SIPMAN & HARRIS 1989; ZOTZ *et al.* 2003). Certain photobiont types are also more common in certain habitats; for example, cyanobacterial photobionts require liquid water for photosynthesis, and such lichens are rare in or absent from dry habitats or those where liquid water is not available. Most temperate lichens have trebouxioid photobionts, while many tropical microlichens feature trentepohlioid symbionts (SIPMAN & HARRIS 1989). The reason for this is unknown but may have to do with differences in the photosynthetic performance of these algae.

Lichens play an important role in ecosystems as pioneer organisms (saxicolous and terricolous species) and in the water and nutrient cycle (epiphytic taxa). Lichens with cyanobacterial photobionts contribute to nitrogen input by fixing atmospheric nitrogen (VITOUSEK 1994; CRITTENDEN 1996). Lichens are used by humans for a large variety of purposes, including food, medicinal applications, dyes, decoration, perfumes, and cosmetics. Most importantly, lichens are used as bioindicators, monitoring air quality, metal contamination, forests conservation status, and even the ozone hole (NASH & WIRTH 1988; HAWKSWORTH & SEAWARD 1990; JEFFREY & MADDEN 1991; RICHARDSON 1992; SEAWARD 1993; KIRSCHBAUM & WIRTH 1995; CONTI & CECCHETTI 2001; NIMIS *et al.* 2002; BARTHOLMESS *et al.* 2004). Some of the reasons that make lichens useful as bioindicators are their wide distribution on a global scale, the generally long-lived thalli, and the capacity of absorbing air particles, including contaminants. In spite of their ecological preferences, lichens are very sensitive to air quality, and the delicate balance between lichen symbionts can be easily broken by contamination with high levels of sulphur dioxide, fluoride, ammonia, and heavy metals (SKYE 1968; GILBERT 1973). This and the fact that lichens are able to colonize different surface types such as rocks and tree barks make them excellent biomonitors of air quality in populated areas (SEAWARD 1992). Standard methods using lichens as biomonitors were developed in Europe and North America (HAWKSWORTH & ROSE 1976; SEAWARD 1992; BARTHOLMESS *et al.* 2004). These methods have been used in the tropics (FERREIRA 1981; BRETSCHNEIDER & MARCANO 1995; MARCELLI 1998), but the results are often not as complete due to the little taxonomic knowledge available. Also, air pollution has been a smaller problem in tropical areas compared to the continuous deforestation of the tropical rainforest and the use of the land for agriculture and pasture (WHITMORE 1990; LÜCKING 1997).

2.1.2 Tropical Ecosystems and Lichens

Tropical rainforests have fascinated naturalists and casual travelers ever since the first contact with this exotic vegetation by Europeans centuries ago. In fact, the term tropical rainforest ('tropischer Regenwald') was first used by the German botanist A. F. W. Schimper in 1898, to describe the forests of the permanently wet tropics (WHITMORE 1990). The most impressing characteristic of this exuberant vegetation, so different from what is found in northern Europe for example, is the enormous species richness, with the largest numbers of co-existing plant and animal species so far reported. These forests are mostly characterized by tropical climates with constant high day-time temperatures and generally high rainfall throughout the year. WHITMORE (1990) uses the term tropical seasonal forest to define those rainforests that exhibit several dry months, which also includes the Atlantic coastal rainforest of Brazil.

Two of the three major neotropical rainforest blocks are located in Brazil, the largest being the Amazon and the other the Atlantic rainforest or Mata Atlântica. This makes Brazil the country with the largest amount of tropical rainforests on the globe. With a total surface area of ca. 8,511,965 km^2 (land), Brazil is the 5th largest country in the world and the largest South American country, occupying about half of the continent. Most of the country (about 80%) is located in eastern South America, bordering the Atlantic Ocean, between the equator and the Tropic of Capricorn. Brazil shares boundaries with every South American country except Chile and Ecuador. The vast territory, apart from the lack of funding, is one of the many difficulties when it comes to preventing and controlling the continuing deforestation of tropical forests in Brazil. Before the European (mostly Portuguese) colonization in the 1500s, the original area coverage of the Mata Atlântica was of about 1.3 million km^2.

The Atlantic rainforest is one of the most endangered biomes in the world. It is considered one of the five most important biodiversity 'hotspots' worldwide (MYERS *et al.* 2000), being one of the biologically richest yet most threatened regions. The Mata Atlântica features an exceptional number of endemic plants (2.7 % of world's total) and vertebrates (2.1 % of world's total) and more than 90% of its natural territory has been lost to deforestation. Eight out of the ten largest cities in Brazil were founded in original Mata Atlântica areas along the coast, where nowadays 70% of the country's population live. Due to urbanization and agriculture, only about 5–8 % of the original vegetation remains partially undisturbed (FIDEM 1987; WHITMORE 1990). In northeastern Brazil, the forest devastation is even more accentua-

ted, where only 2% of this extremely rich biome is still undisturbed, and it occurs mostly in isolated scattered throughout a landscape dominated by agricultural uses.

To illustrate the complexity of this biome, the Federal Decree 750/93, which regulates the use of natural resources and deforestation in the region, defines and delimitates Brazil's Atlantic rainforest as follows: "*The Atlantic Forest is to be considered as forest formations and associated ecosystems inserted in the Atlantic Forest domain, with the following delimitation established by the Brazilian Vegetation Map of IBGE (1998): ombrophilous dense Atlantic forests, mixed ombrophilous forests, open ombrophilous forests, semidecidual satational forests, decidual stational forests, mangroves, restingas, altitudinal grasslands, the countryside swamps, and the northeastern forest enclaves*".

In the Brazilian northeast, the Atlantic rainforest, or Mata Atlântica, is represented mostly by a narrow tropical forest strip along the coast, extending from Rio Grande do Norte to Bahia state (WHITMORE 1990). It is characterized as a perennial forest with pronounced dry season, including lowland coastal forests with areas of restinga (sand-bank formations) and mangroves. Some patches of Mata Atlântica are also found as so-called Brejos de Altitude, i.e. high altitude tropical vegetation isolated from the coast and nested within drier Caatinga or transitional vegetation (ANDRADE-LIMA 1961, 1964; RIZZINI 1977). In the southeastern to southern parts of Brazil, the Atlantic rainforest mostly covers areas of higher altitudes and higher humidity, such as the Serra da Mantiqueira, Serra do Mar and Serra do Espinhaço, in the States of São Paulo, Rio de Janeiro and Minas Gerais.

One of the consequences of the deforestation is the increasing drought, causing an even more prolonged dry season, which subsequently affects the already reduced and overstressed rainforest remnants. This was observed by CÁCERES *et al.* (2000) a in a survey of the foliicolous lichen biota on remnants of Atlantic rainforest from Pernambuco state, northeastern Brazil. In this work, it was shown that the fragmented Atlantic rainforest remnants only conserve a small part of the overall foliicolous lichen diversity and that conservation of larger areas and corridors is needed to maintain high levels of species diversity in this threatened ecosystem. Also, it could be shown that selected logging not only reduces foliicolous lichen diversity but also alters community structure and particularly threatens those communities adapted to light gaps in the forest understory.

Only recently, it has been established that the tropics house ecosystems with the greatest lichen diversity in the world (GALLOWAY 1991, 1992; GRADSTEIN 1992; LÜCKING 1995a; APTROOT 1997a, b; APTROOT & SIPMAN 1997; KOMPOSCH & HAFELLNER 1999, 2000,

2002; LÜCKING & MATZER 2001; COPPINS & WOLSELEY 2002; SIPMAN & APTROOT 2001; LÜCKING *et al.* 2004). It was always a common belief that extratropical regions had the greatest global lichen diversity, which was supported by so many years of lichenological research and collections in Europe and North America (POELT 1969; CLAUZADE & ROUX 1985; PURVIS *et al.* 1992; SANTESSON 1993; WIRTH 1995; BRODO *et al.* 2001). Yet, with the increasing amount of studies and field trips to tropical regions, more and more species have been reported and also described from tropical Asia and Australia (APTROOT 1997a, b; APTROOT *et al.* 1997; APTROOT & SEAWARD 1999; APTROOT & SIPMAN 2001; LÜCKING *et al.* 2001), Africa (SWINSCOW & KROG 1988; LÜCKING & KALB 2002; FRISCH *et al.* 2006), and Central and South America (KAPELLE & SIPMAN 1992; LÜCKING 1992, 1995b; KOMPOSCH & HAFELLNER 1999, 2000; BÜDEL *et al.* 2000; BREUSS 2000, 2001, 2004; CHAVES *et al.* 2004; LÜCKING *et al.* 2006; NELSEN *et al.* 2006). Also, more and more revisions and monographs are becoming available for tropical lichens (HALE 1974, 1975, 1976a, 1976b, 1978, 1981; KALB 1987; KALB & VĚZDA 1988a, b; MOBERG 1990; BRAKO 1991; STAIGER & KALB 1995; TEHLER 1997; AHTI 2000; MARBACH 2000; STAIGER 2002; KALB *et al.* 2000, 2004; FRISCH *et al.* 2006).

The checklist of lichens from Brazil, published by Marcelo Marcelli on the lichen checklist website (MARCELLI 2005), contains about 3,000 records, the largest number of any country in the world. Foliicolous lichens alone amount to more than 300 species (LÜCKING & KALB 2000). Yet, for several reasons, our knowledge of the Brazilian lichen flora, presumably one of the richest in the world, is still rudimentary for many areas and taxonomic groups. First, there is a clear geographical and taxonomic bias with regard to published floras towards central and southern Brazil and towards macrolichens (chiefly Parmeliaceae) and foliicolous lichens. Few reliable data exist for the diversity of crustose microlichens and for Amazonian and northeastern Brazil. Secondly, few modern revisions exist for many groups, for which names have been published and included in the checklist. This is particular true of crustose microlichens on rock and bark surfaces, which in a country like Brazil, with vast areas of dry vegetation and continental lowland rainforest, will account for at least 50 % of its lichen diversity. Although these lichens have been extensively sampled by various workers, the few modern accounts available do not correspond to the diversity to be expected.

2.1.3. Ecology and conservation of tropical Lichens

A continuously growing number of ecological studies on tropical lichens in all tropical regions have been carried out for the past few decades (CORNELISSEN & TER STEEGE 1989; CORNELISSEN & GRADSTEIN 1990; MONTFOORT & EK 1990; MARCELLI 1992; WOLF 1993a–c, 1994, 1995; APTROOT 1997a, b; WOLSELEY & AGUIRRE-HUDSON 1991; LÜCKING *et al.* 1998a–c, 1999a–c; KOMPOSCH & HAFELLNER 1999, 2000, 2002; TER STEEGE *et al.* 2000; NÖSKE 2004; HOLZ & GRADSTEIN 2005), although the actual state of knowledge about this subject is very far from complete or satisfactory. MERWIN & NADKARNI (2002) give an overview over the last 100 years of research on the ecology of lichens and bryophytes in the tropics. This bibliographic guide shows also that ecological research on lichens in the tropics is much less than on bryophytes, and that the neotropics are much better studied than other tropical regions.

Although a few historical papers include quite accurate observations on the ecology of tropical lichens, modern studies were first made in the early seventies and eighties on foliicolous lichens from Colombia and Brazil (NOWAK & WINKLER 1971, 1975; SCHELL & WINKLER 1981). These authors were the first to use quantitative and multivariate analytical methods in tropical lichen ecology. Similar methods were then used in a number of studies on foliicolous lichens, mainly in Costa Rica (LÜCKING 1995a, b, 1997, 1998a, b, 1999a-c), but also in Mexico (HERRERA-CAMPOS *et al.* 2004), Guatemala (BARILLAS *et al.* 1993), Ecuador (LÜCKING 1999d), and by the author of the present work in Brazil (CÁCERES *et al.* 2000). These studies showed that foliicolous lichens demonstrate clear altitudinal and habitat preferences, being most diverse in lowland rainforests and almost absent from deciduous dry forest and high (sub)andine zones. While phorophyte preferences are hardly apparent, most species show clear correlations with microclimatic parameters and very different communities are observed in the shaded understory, small light gaps, and the exposed canopy of rainforests. Due to these characteristics and their slow and local dispersal through rain water, foliicolous lichens are good indicators of anthropogenic disturbance levels and ecological continuity (LÜCKING 1997; CÁCERES *et al.* 2000).

Corticolous lichens were begun to be studied in the late eighties and early nineties (CORNELISSEN & GRADSTEIN 1990; TER STEEGE *et al.* 2000). CORNELISSEN & TER STEEGE (1989) in Guyana and MONTFOORT & EK (1990) in French Guiana found that epiphytic lichens and bryophytes showed vertical zonation from the forest understory to the canopy, as well as certain phorophyte preferences. The most detailed study so far on tropical epiphytic lichens and bryophytes was the one presented by WOLF (1993a-c, 1994, 1995). This author

used multivariate ordination and classification methods to analyze a large data matrix from several hundred samples made in different forest types in Colombia and found significant patterns in altitudinal zonation, community formation, and correlations with certain substrate parameters such as bark type, bark pH, and substrate nutrient content. Similar, though less detailed and more local studies were presented by BIEDINGER & FISCHER (1996) in central Africa and more recently by NÖSKE (2004) and NÖSKE & SIPMAN (2004) in Ecuador and by HOLZ & GRADSTEIN (2005) in Costa Rica. ZOTZ (1999) and ZOTZ *et al.* (2003) attempted to explain the patterns of altitudinal zonation of tropical lichens by the ecophysiological characteristics of the different groups and growth types.

The use of lichens as bioindicators of environmental changes in the tropics, as well as aspects of their conservation, was first approached in detail by Wolseley and her collaborators in Thailand (WOLSELEY & AGUIRRE-HUDSON 1991, 1997a, b; WOLSELEY *et al.* 1994; WOLSELEY 2002). In her study of montane rainforests in Ecuador, NÖSKE (2004) demonstrated the use of epiphytic lichens and bryophytes as bioindicators of anthropogenic disturbances. In a more applied approach, PÉRES (2005) compared the lichen biota of three different forest management types in southern Mexico and found that sustainable management conserved higher macrolichen diversity. A very interesting pioneering experiment was performed by NADKARNI (2000) in Costa Rican cloud forest. Canopy branches were completely stripped off their epiphyte cover, including vascular epiphytes (abundant), bryophytes (abundant), and lichens (rare), to observe the recovery of the epiphyte mats. No re-growth was observed until after five years, and the first organisms then to colonize the bare branches were crustose and foliose lichens, indicating that lichens play an important role in both primary and secondary succession of tropical epiphyte communities.

While these studies either largely neglected crustose microlichens or were performed in habitats where these lichens are comparatively rare, MARCELLI (1992) was the first to investigate the lichen biota of tropical mangrove forests in southeastern Brazil, including many crustose taxa. He found that lichen species basically responded to microclimatic parameters (illumination and humidity), which showed a distinct zonation from the margins to inner parts of mangrove vegetation, but also to tree bark characteristics, including salt content. Much more recently, KOMPOSCH & HAFELLNER (1999, 2000, 2002) presented a detailed study on the ecology of tropical lowland rainforest lichens, using the crane system at the Orinoco river in Venezuela to access the different forest zones and to compare rainforest with savanna lichen communities. This study was the first in which an attempt was made to identify the

bulk of crustose microlichens, which represent a large part of the lichen diversity in tropical lowland and lower montane forests between sea level and 2000 m altitude. Yet, the lack of a solid taxonomy and identifications tools for many crustose lichens groups until most recently prevented from large-scale and detailed ecological studies of tropical crustose microlichens using a quantitative approach. Therefore, the central objective of the present work was to combine, for the first time, a thorough taxonomic treatment focused on crustose microlichens of a large tropical rainforest area (northeastern Brazil) with a quantitative sampling approach and multivariate data analysis, in order to present a solid ecogeographical study of tropical crustose microlichens and to assess their potential as bioindicators of anthropogenic disturbance and ecological continuity of tropical rainforests in northeastern Brazil.

2.1.4. Lichenology in Brazil

The lichenological exploration of Brazil began with the first official scientific expedition by the German botanist C. F. P. Martius [*1794-1868*] and the German zoologist J. B. R. Spix [*1781-1826*], who travelled from south-eastern Brazil to the Amazonas from 1817 to 1820 and collected about 6,500 plant specimens, among which were several hundred lichens (MARCELLI 1998). These were reported by ESCHWEILER (1833), as well in *Flora Brasiliensis* (MARTIUS 1828-1834), but the material on which the descriptions were based was unfortunately lost during World War II (MARCELLI *et al.* 1998).

In the mid nineteenth century, the English bryologist Richard Spruce [*1817-1893*] collected abundant lichen material in the Amazon region, which was first treated by LEIGHTON (1866) and later by MÜLLER ARGOVIENSIS (1890, 1892a, b, 1893). The collections made by Spruce are considered the most important of the Amazon region to date (SEAWARD & FITZGERALD 1996), and included many new species especially of foliicolous lichens (see also SANTESSON 1952). Spruce was followed in the years 1873 to 1875 by the Scottish botanist James William Helenus Trail [*1851-1919*], whose collections were published mainly by STIRTON (1878) and MÜLLER ARGOVIENSIS (1892b). The French botanist Auguste François Marie Glaziou [*1833-1906*] spent 35 years in Brazil (from 1861 to 1895) and during this time gathered a huge number of lichen collections mainly in the south-eastern states of Rio de Janeiro, São Paulo, and Minas Gerais. The material was reported by KREMPELHUBER (1868, 1876), NYLANDER (1869), and MÜLLER ARGOVIENSIS (1889, 1890, 1893). Another foreigner resident and one of the most productive lichen collectors was the Spanish mycologist Juán Ignacio

Puiggari [*1823-1900*], who came to Brazil in 1877 and assembled the most significant lichen collection from São Paulo and adjacent areas. His material was mainly treated by MÜLLER ARGOVIENSIS (1895a, b). Other important gatherings were made by the German botanist Ernst Heinrich Georg Ule [*1854-1915*], between 1883 and 1912, chiefly in southern and central Brazil but later also in the Amazon and southern Bahia. Again, his collections were studied first by MÜLLER ARGOVIENSIS (1890, 1891, 1895c).

Although visiting Brazil only for about four months in 1885, the studies made by the Finnish lichenologist Edward August Vainio [*1853-1929*] are considered the historically most important contributions to Brazilian lichenology (MARCELLI 1998; MARCELLI & AHTI 1998). This is because Vainio was the first genuine lichenologist to visit this vast country, and his collections were much more detailed and specific than other lichen collections made during this period. Vainio chiefly collected in the states of Minas Gerais and Rio de Janeiro and eventually published more than 600 taxa from these gatherings, almost half of which were new to science (VAINIO 1887, 1890a, b, 1894). Vainio's work had much more impact on the development of lichenology than the many papers by Müller Argoviensis, which is why he is considered the 'Father of Brazilian Lichenology' (MARCELLI & AHTI 1998).

At the beginning of the twentieth century, the Austrian botanists Victor Felix Schiffner [*1862-1944*] and Richard von Wettstein [*1863-1931*] assembled what is probably the largest single collection of plants and cryptogams from Brazil ever made. More than 35,000 specimens were brought back to Austria, more than half of them cryptogams. The lichens were studied by ZAHLBRUCKNER (1909), who also published on collections made by the Brazilian botanist Leônidas Botelho Damázio [*1854-1905*] in Minas Gerais, by F. Höhnel [*1852-1920*] in Rio de Janeiro, and by Ule in the Amazon region (ZAHLBRUCKER 1902, 1904, 1905, 1908a, 1908b). It is worth mentioning that during this period, Damázio was the only notable local lichen collector in Brazil (MARCELLI 1998).

Besides Vainio's collecting trips to Minas Gerais and Rio de Janeiro, the most important historical contributions to Brazilian lichenology were made by the Swedish botanist Gustaf Oskar Andersson Malme [*1864-1937*]. Financed by a fund established by the Swedish doctor and botanist Anders Fredrik Regnell [*1807-1884*], who lived and worked in Brazil for more than 40 years, Malme travelled to Brazil twice, collecting about 6,000 lichens during the First Regnellian Expedition from 1892 to 1894. His collections chiefly originated from the lichenologically unexplored states of Rio Grande do Sul and Mato Grosso, and like Vainio, Malme himself worked on his collections and published many new species based on this material

(MALME 1897, 1902, 1923, 1924a, b, 1926a–c, 1927, 1928, 1929a, b, 1934a–c, 1935, 1936a, b, 1937). Malme's gatherings were also studied by LYNGE (1914, 1924a, b), REDINGER (1933a, b, c, 1934, 1935, 1936, 1940), MAGNUSSON (1934a, b), MOTYKA (1936, 1938), and SANTESSON (1943, 1952). Especially Malme's and Redinger's papers are still among the most important references regarding Brazilian and tropical lichens in general, and Santesson's monograph on foliicolous lichens (SANTESSON 1952), with a large number of specimens and taxa revised for Brazil, is considered a milestone in lichenology (TIBELL 1997).

The first significant contributions to lichenology by a local researcher were undoubtedly made by the Brazilian mycologist Augusto Chaves Batista [*1916-1967*] and his students in the state of Pernambuco (CARNEIRO 1968; DA SILVA & MINTER 1995; LÜCKING *et al.* 1998, 1999a, b). The work of Batista's group impacted mycology and lichenology far beyond the borders of Brazil, not only because of the immense number of new taxa described, but also because Batista and his students consequently applied dual nomenclature also to lichenized fungi, describing many new names for anamorphs of chiefly foliicolous lichens (LÜCKING *et al.* 1998). Batista initiated what was called the 'Northeastern Tradition' (PEREIRA 1996, 1998; MARCELLI 1998), continued by his student Lauro Xavier Filho [*1940-*] and Xavier Filho's student Eugênia Cristina Pereira [*1960-*] until the present. Both Xavier Filho and Pereira focused their studies on lichen chemistry and the diverse applications of secondary lichen substances, including the production of lichen metabolites from cell cultures and cell immobilization (PEREIRA *et al.* 1995a, b, 1999, 2002; PEREIRA 1998; FONTANIELLA *et al.* 2000; BLANCO *et al.* 2002; FALCÃO *et al.* 2002; DE CARVALHO *et al.* 2005). Several other groups specialising on lichen chemistry and its applications emerged in the states of Paraná, Mato Grosso do Sul, and São Paulo (GORIN *et al.* 1988, 1993; HONDA *et al.* 1995; SAIKI *et al.* 1997; HONDA & VILEGAS 1998; MARCELLI 1998).

The second half of the twentieth century initiated the modern systematic research on lichenized fungi, with many publications treating or citing Brazilian material. Among those, one may especially mention the works of Hale on Parmeliaceae (HALE 1975, 1976a, b). The most significant recent collections by a foreign researcher are those made by the German lichenologist Klaus Kalb [*1942-*], which together with Vainio's and Malme's collections are now the primary reference for anyone studying lichens in Brazil (KALB 1981, 1987, 2001, 2004; KALB & VĚZDA 1987; BRAKO 1991; KASHIWADANI & KALB 1993; KALB & ELIX 1995; STAIGER & KALB 1995, 1999; LÜCKING & KALB 2000; MARBACH 2000; STAIGER 2002; KALB *et al.* 2000, 2004; FRISCH *et al.* 2006). Important collection trips were also made by the

Finnish lichenologist and specialist in Cladoniaceae, Teuvo Ahti [*1934*-], who published several papers on Cladoniaceae and cited many species in his *Flora Neotropica* monograph (AHTI 2000). Beginning in the early 1970s, the Uruguayan lichenologist Héctor Saúl Osorio [*1928*-.] initiated a detailed inventory of the lichen biota of southern Brazil (e.g. OSORIO 1973, 1981, 1992, 1998), later continued by his collaborator and Brazilian lichenologist Mariana Fleig [*1940*-] and her student Sionara Eliasaro [*1962*-] in Rio Grande do Sul and Paraná (e.g. OSORIO & FLEIG 1982, 1994; FLEIG 1985, 1990, 1995, 1999; FLEIG *et al.* 1995; ELIASARO & ADLER 1997, 2000; ELIASARO & DONHA 2003; FLEIG & GRÜNINGER 2000), by Klaus Kalb's collaborator Marcelo Marcelli [*1955*-] and his students in São Paulo and central Brazil (PEREIRA & MARCELLI 1989; MARCELLI 1991, 1992, 1993, 1995; AHTI & MARCELLI 1995; MARCELLI & RIBEIRO 2002), and by the Argentinian lichenologist Lidia Itati Ferraro in southern Brazil (FERRARO & ELIX 1993; FERRARO & LÜCKING 2000).

After Stirton's (1879) classic paper, foliicolous lichens were first monographed by SANTESSON (1952), who mentioned more than 150 species for Brazil. The group was further studied in Brazil by RICCI & TOMASELLI (1958), but it took another 23 years until SCHELL & WINKLER (1981) presented a first ecogeographical analysis based on collections from Rio Grande do Sul state. Collections made by Klaus Kalb were treated in several recent publications (KALB & VĚZDA 1988a, b; VĚZDA 1994, 2004), including a complete checklist presented by LÜCKING & KALB (2000). Foliicolous lichens from Brazil, including several new species, were also reported by Ferraro and collaborators (FERRARO 1997; LÜCKING & FERRARO 1997; FERRARO & LÜCKING 1997, 1999, 2000, 2003; FERRARO *et al.* 2001), and a small ecological paper was presented by LOMBARDI *et al.* (1999). Based on a M.Sc. thesis, the author of the present work and her collaborators described several new species of foliicolous lichens from Brazil (CÁCERES 1999; LÜCKING & CÁCERES 1999; CÁCERES & LÜCKING 2000) and presented an ecological and biogeographical study on the group in the Atlantic rainforest (CÁCERES *et al.* 2000). Later, the author focused her interest on crustose corticolous lichens (LÜCKING & CÁCERES 2004), which are also the subject of the present work.

The publications mentioned above document the output of floristic and taxonomic contributions on lichens mainly from northeastern, central and southern Brazil by local researchers, balancing the many studies by foreign workers which usually extracted most or all of the material from the country. Thus, the main collections now available in Brazil are those gathered by Batista, Xavier Filho, Pereira, Fleig and Marcelli and their students (MARCELLI & RIBEIRO 2002; BENATTI 2005; CANÊZ 2005; KÄFFER 2005; SPIELMANN 2005;

JUNGBLUTH 2006), housed at the Instituto de Botânica in São Paulo, and the Federal University of Pernambuco in Recife (URM). Marcelli is also the founder of the Checklist of Lichens from Brazil, available online at http://www.biologie.uni-hamburg.de/checklists/southamerica/ brazil_l.htm, which currently lists some 3,000 species. This number probably underestimates the diversity expected from this vast country, but includes many old names that have to be revised, while many more species remain to be discovered.

2.1.5. Objectives and Concept of the Study

The present work was carried focusing on different aspects concerning the diversity and ecology of corticolous crustose and microfoliose lichens in northeastern Brazil, including the main vegetation types of Mata Atlântica, Caatinga, and Brejos de Altitude. For this purpose, the following objectives and hypotheses were formulated:

- Determine the number of species of corticolous crustose and microfoliose lichens that occur in northeastern Brazil and their contribution to overall lichen diversity in this area. The total number of lichens initially estimated for the area was 1,000, of which corticolous crustose and microfoliose lichens were assumed to contribute 50%, foliicolous lichens 25%, and macrolichens and lichens on other substrata another 25%. Thus, the number of lichens found in this study was estimated to be about 500 species.
- Provide identification tools to the genera and species of corticolous crustose and microfoliose lichens of northeastern Brazil.
- Analyse differences and similarities in lichen species richness and community composition between the three major vegetation types present in northeastern Brazil: Mata Atlântica, Caatinga, and Brejos de Altitude. Determine characteristic species of each vegetation type.
- Compare lichen species richness of individual fragments of Atlantic rainforest remnants and assess the impact of deforestation and habitat loss on local and overall lichen diversity.
- Analyse the influence of tree bark characteristics and phorophyte species on lichen species composition, richness, and area cover, in a selected fragment of Atlantic rainforest, to assess how tree diversity affects corticolous lichen diversity and the spatial distribution of lichen species within the forest.

- Compare opportunistic and quantitative sampling methods to assess how well each method recovers and estimates lichen species richness of Atlantic rainforest fragments. Based on this, provide more accurate estimates of lichen species richness for individual fragments.

The four individual publications resulting from the completion of this study (see page 06 of this volume for details) will be presented as follow, with focus on the bellow mentioned topics:

(1) Diversity

- Taxonomic composition
- Alpha-, Beta- and gamma-diversity
- Appropriate sampling methods to estimate lichen diversity

(2) Phenotypic characters and ecology

- Criteria for elaboration of the identification key
- Distribution of diagnostic characters in each vegetation zone

(3) Conservation

2.2. Material and Methods

2.2.1. Study Area

With a surface area of ca. 8,511,965 km^2 (land), Brazil is the fifth largest country in the world and the largest South American country, occupying about half of the continent. Most part of the country (about 80%) is located in eastern South America, bordering the Atlantic Ocean, between the equator and the Tropic of Capricorn. The national territory is politically subdivided in 26 states and a Federal District, which are grouped in five geographical regions: the northern, the northeastern, the southeastern, the southern, and the central region.

The northeastern Region of Brazil is composed by the states of Maranhão, Piauí, Ceará, Rio Grande do Norte, Paraíba, Pernambuco, Alagoas, Sergipe and Bahia. This region comprises three main vegetation types: (1) the coastal Atlantic rainforest, (2) the Caatinga, and (3) the Brejos de Altitude (ANDRADE-LIMA 1961, 1964; RIZZINI 1977; WHITMORE 1990; MARCELLI 1998; SILVA FILHO *et al.* 1998). Before the European colonization in the sixteenth century, the Atlantic rainforest covered an area of about 1.300.000 km^2, extending from northeastern to southern Brazil and covering 17 states. In the Brazilian northeast, the Atlantic rainforest or

Mata Atlântica is represented mostly by a narrow tropical forest strip along the coast, extending from Rio Grande do Norte to Bahia state (WHITMORE 1990). It is characterized as a perennial forest with pronounced dry season, including lowland coastal forests with areas of Restinga or sand-bank formations and mangroves. Some patches of Mata Atlântica are also found as Brejos de Altitude, high altitude tropical vegetation isolated from the coast and nested within dry Caatinga or transitional vegetation (ANDRADE-LIMA 1961, 1964; RIZZINI 1977). In the southeastern to southern parts of Brazil, the Atlantic rainforest mostly covers areas of higher altitudes and higher humidity, such as the Serra da Mantiqueira, Serra do Mar and Serra do Espinhaço, in the States of São Paulo, Rio de Janeiro and Minas Gerais.

The trees in the Atlantic rainforest of northeastern Brazil can reach up to 40 m height, most of them reaching at least 15–25 m (ANDRADE-LIMA 1964; RIZZINI 1977). Typical trees from this part of the Mata Atlântica include *Tapirira guianenesis* Aubl. (Anacardiaceae), *Aspidosperma discolor* A. DC. (Apocynacea), *Copaifera nitida* Mart. ex. Hayne and *Sclerobium densiflorum* Benth. (Caesalpiniaceae), *Clusia nemorosa* G.F.W. Mey., *Symphonia globulifera* Linn. (Clusiaceae), *Andira nitida* Mart. (Fabaceae), *Sacoglottis guianensis* Benth. (Humiriaceae), *Helicostylis tomentosa* Rusby, *Clarisia racemosa* Ruiz & Pav. (Moraceae), *Cupania vernalis* Cambess. (Sapindaceae), and *Apeiba albiflora* Ducke. (Tiliaceae), among many others. Floristically, the northeastern Atlantic rainforest is different from the southern part and shows affinities with the Amazon rainforest and the Caatinga vegetation (MELO SANTOS *et al.* 2006). The Atlantic rainforest as a whole has been identified as one of 25 world diversity hotspots (MYERS *et al.* 2000), and several large-scale projects are currently under way to inventory its organismic diversity, such as the NORTHEASTERN ATLANTIC COASTAL FOREST PROJECT or PROJETO MATA ATLÂNTICA NORDESTE (http://www.nybg.org/bsci/res/bahia), the project MATA ATLÂNTICA – SCIENCE AND TECHNOLOGY FOR THE MATA ATLÂNTICA (http://www.mata-atlantica.ufz.de), and the related project STRUCTURE AND REGENERATION OF FRAGMENTS OF ATLANTIC RAINFOREST IN PERNAMBUCO (http://www.biologie.uni-ulm.de/mataatlantica). In the course of these inventories it was found that a single hectare of Atlantic rainforest harbours up to 450 different tree species. The level of endemism is extremely high, with over 50% of the tree species and over 90% of the amphibians being endemic to this biome (LYNCH 1979; MORI *et al.* 1981).

The Brazilian Atlantic rainforest is one of the most endangered vegetation types in the world. Nowadays, due to deforestation and land use change, only about 5–8 % of the original vegetation remains partially undisturbed (FIDEM 1987; WHITMORE 1990). In northeastern Brazil, the forest devastation is even more accentuated, where only 2% of this extremely rich

biome is still left untouched. The increasing drought is one of the consequences of deforestation which in turn affects the already reduced and overstressed forests reminescents (CÁCERES 1999).

2.2.2. Field Work and Collection Sites

The field work was carried out during three field trips to northeastern Brazil from October to November 2000, April to May 2001 and September to October 2002. Collections were made in a total of 22 localities (CÁCERES 2007), distributed along the Atlantic coast, within a range of about 700 km from north to south, covering the states of Rio Grande do Norte, Paraiba, Pernambuco, Alagoas, and Sergipe (Figure 1). The collecting sites were chosen with the purpose of covering as many forest remnants and vegetation types as possible along the whole extension of the northern Atlantic rainforest and adjacent Caatinga vegetation.

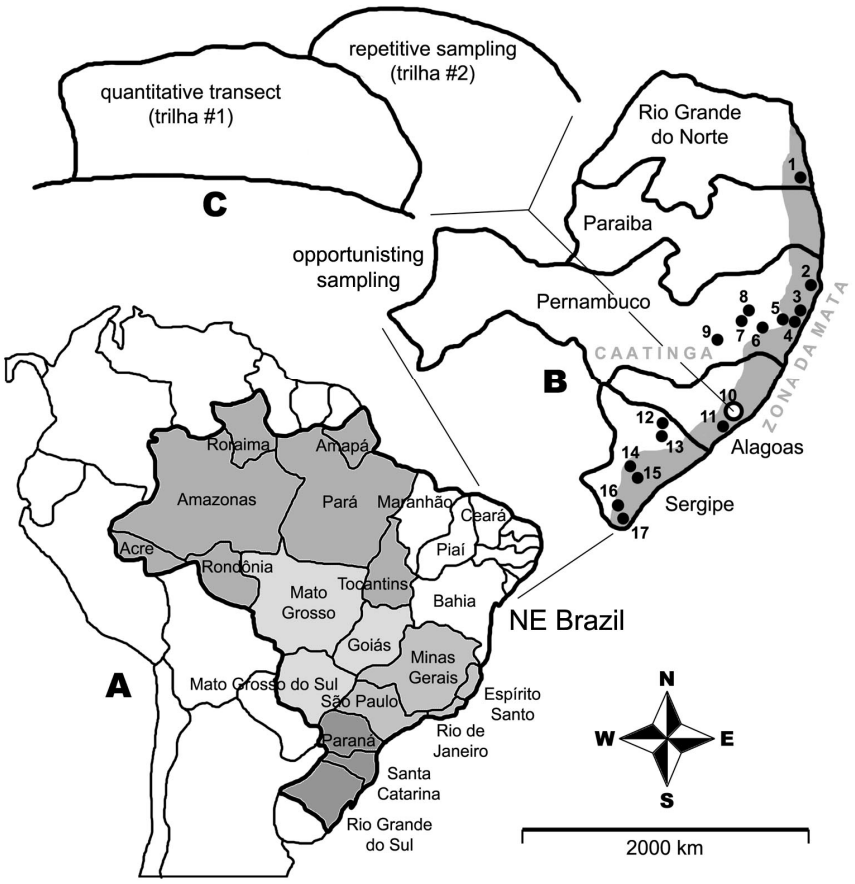

Figure 1. A: Brazil and its five regions. B: The eastern coastal states with localities studied by opportunistic sampling. C: Two trails sampled at RPPN Fazenda São Pedro for repetitive and quantitative sampling.

Three different sampling methods were employed: (I) one-time non-quantitative opportunistic sampling per site ('opportunistic'), (II) three-times repetitive non-quantitative opportunistic sampling at a single site ('repetitive'), and (III) quantitative transect sampling at a single site ('quantitative'). Opportunistic sampling was applied to inventory the corticolous lichen diversity of 21 remnants of Mata Atlântica, Caatinga and Brejos de Altitude (CÁCERES 2007; CÁCERES *et al.* 2007a). Repetitive sampling was applied to one site, the RPPN Fazenda São Pedro in Pilar, Alagoas, which was visited three times to assess the effect of multiple visits on the lichen diversity inventoried (CÁCERES *et al.* 2007c). Quantitative sampling was employed at the same site, the RPPN Fazenda São Pedro, although a different, parallel, non-overlapping trail, to study potential phorophyte preferences of corticolous lichens and to compare the results of quantitative versus opportunistic sampling to accurately estimate lichen species richness (CÁCERES *et al.* 2007b, c). For quantitative sampling, collections were made along a transect laid on one of the main trails, and a total of 47 phorophytes belonging to 16 different tree species were selected. Sample rectangles of 60 × 20 cm^2 each were placed on the trunk of each phorophyte at breast height and all lichen thalli located inside each of the 47 sample rectangles were registered and identified to species level using morphological, anatomical and chemical characters (CÁCERES *et al*. 2007b). The main difference between methods I and II was the number of phorophytes studied and the number of collected lichen samples, in addition to the fact that for method II, the same area within the site and partially the same phorophytes were revisited and resampled based on previous sampling experience. The main difference of method III was the different approach towards the selection of phorophytes and lichen specimens by means of sample rectangles, within which all lichen specimens were identified.

For the ecological analyses in the RPPN Fazenda São Pedro, the following nine parameters were determined for each phorophyte tree and sample (CÁCERES *et al.* 2007b): (1) circumference at breast height (as a relative estimate for tree age); (2) angle (orientation) of sample center point, using north as 0 and measuring clockwise between 0 and 360 degrees; (3) bark pH; (4) bark structure; (5) presence and size of bark lenticels; (6) degree of water repellence; (7) presence of milk sap; (8) degree of bark shedding; and (9) relative light intensity or diffuse site factor. For the purpose of comparing different sampling methods between localities (CÁCERES *et al.* 2007c), all collected lichen species were scored with respect to four binarily coded parameters: (1) abundance (abundant versus rare), (2) conspicuousness (conspicuous versus inconspicuous), (3) fertility (commonly fertile versus commonly sterile),

and (4) distinctiveness (recognizable as distinct species versus cryptic). Abundance was assessed based on the total number of collected specimens in combination with the number of sites where a species was collected. Conspicuousness was based on the notion whether a thallus of a given species was usually visible from a certain distance in the field or only at close-up or through a handlens or stereomicroscope. Fertility referred to the usual presence or absence of ascomata necessary for identification, and distinctiveness separated macroscopically recognizable from cryptic species. These assessment were based on the hypothesis that species are more likely to be collected by opportunistic sampling if they are abundant, conspicuous, fertile (sterile specimens more commonly being rejected because of less likeliness of positive identification), and/or distinctive as species, while rare, inconspicuous, commonly sterile and/or cryptic taxa are more likely to be collected by quantitative sampling. For each species, the four binary codes were added to a combined score CS, ranging from 0 (species rare, inconspicuous, sterile, and cryptic) to 4 (species abundant, conspicuous, fertile, and distinctive). Depending on their presence/absence within the localities for which the different sampling methods were applied, the lichen species were classified into seven different categories.

2.2.3. Identification of Lichen Taxa

The identification key for tropical lichens by SIPMAN (2003) available online (http://www.bgbm.org/sipman/keys/neokeyA.htm) and the LIAS genus key (RAMBOLD & TRIEBEL 1995–2006), both, were used for the identification of tropical crustose lichens at generic level, in addition to recent monographic and revisionary treatments for larger groups (BRAKO 1991; HARRIS 1986, 1989, 1995; MARBACH 2000; STAIGER 2002; FRISCH *et al.* 2006). For the identification and nomenclature of more specific groups at species level, many individual treatments were used which are cited under each genus (CÁCERES 2007). In addition to these sources, the LIAS Glossary (RYAN et al. 2005–2006) online was consulted for the construction of the key to genera and species, and the specific terminology is found there as well.

Identification work was chiefly carried out at the Chair of Plant Systematics, Department of Mycology of the University of Bayreuth in Germany (Prof. Dr. G. Rambold) and at the Field Museum of Natural History in Chicago (Dr. R. Lücking, Dr. T. Lumbsch), with visits to the Lichenological Institute Neumarkt, Germany (Prof. Dr. K. Kalb), the Botanischer

Garten & Botanisches Museum Berlin-Dahlem, Germany (Dr. H. Sipman), and the CBS - Central Bureau for Fungal Cultures, Baarn, The Netherlands (Dr. A. Aptroot).

Representative sets of specimens are deposited in the following herbaria: Instituto de Micologia, Universidade Federal de Pernambuco, Brasil (URM); Botanischer Garten & Botanisches Museum Berlin-Dahlem, Germany (B); and Field Museum of Natural History, Chicago, USA (F).

2.2.4. Data Analysis

Statistical analysis was performed using STATISTICA™ 6.0 and PC-ORD 4.0 (McCune & Mefford 1999; McCune & Grace 2002). For the purpose of comparing different vegetation types and localities across the study area (Cáceres *et al.* 2007a), lichen species composition at each site was used to ordinate and classify sites by applying non-metric multidimensional scaling (NMS) as ordination method and cluster analysis based on Sørensen's coefficient of dissimilarity as classification method. NMS provides a two-dimensional projection of the sample points (localities) in the hyperdimensional lichen species space, by transforming their spacial coordinates into ranks and develop a two-dimensional projection through an iteration process (Jongman *et al.* 1995; McCune & Grace 2002).

Indicator species analysis was performed to detect species that can be classified as characteristic of a given vegetation type. For that purpose, a Monte-Carlo test was performed on the original frequency (number of sites where species was present) and abundance data (categorized number of collections per site), that is the data were mixed randomly with 1000 repetitions, and it was tested whether the observed data distribution deviated significantly from the random distribution derived from the Monte-Carlo test, i.e. whether a given species was significantly more abundant and frequent within a given vegetation type than expected by random (McCune & Grace 2002).

Lichen species unique to each of the three major vegetation types (Atlantic rainforest, Brejos de Altitudes and Caatinga) were used to test whether the observed frequency of selected character states (systematic affinity, morphology, anatomy, chemistry) among vegetation types differed significantly from the expected frequency based on the overall frequency of the character state. Observed versus expected frequencies were compared within each vegetation type across all states of a given character, and a Chi-Square test was used to determine statistical significance of the observed differences (Cáceres *et al.* 2007a).

For the analyses of lichen communities and the relationship with the studied parameters and the comparison among the lichen compositions of different vegetation types (CÁCERES *et al.* 2007b), the data were analyzed using various ordination and classification methods (GREIG-SMITH 1978; GAUCH 1982; JONGMAN *et al.* 1995; MCCUNE & GRACE 2002), in order to detect data structure shared among different methods. Sample points were ordinated using two methods of indirect gradient analysis: non-metric multidimensional scaling (NMS) and detrended correspondence analysis (DCA). In addition, canonical correspondence analysis (CCA) was used as ordination method of direct gradient analysis, including species/sample score correlations with the measured environmental parameters in the calculation of two-dimensional sample scores. NMS is the only approach that does not make any assumptions on the data and is therefore the most robust methods regarding to data structure. DCA assumes one dominant underlying gradient and often fails to detect more than one gradient in the data. CCA has the same limitations, but in addition restricts data structure to the correlation with measured sample parameters, thus neglecting meaningful structure in the species abundance data that are not correlated to the sample parameters (MCCUNE & GRACE 2002). Comparison of NMS, DCA, and CCA was therefore used to detect possible conflict between analytical methods. Cluster analysis was employed to assess hierarchical grouping of samples based on lichen species composition. Correlation of detected clusters with environmental and community parameters was assessed using non-parametric Kruskal-Wallis ANOVA and Mann-Whitney U-test, as well as Spearman rank correlation. In addition, indicator species analysis was applied using a Monte-Carlo simulation to detect species that have significant preferences for certain tree species or sample groups apparent in the multivariate analysis.

The symmetrical dissimilarity matrix resulting from the NMS and cluster analysis was subjected to spatial autocorrelation analysis and analysis of phorophyte dependence. The 47 sampled trees were arranged spatially in four groups I, II, III, and IV, according to their location within the transect. Kruskal-Wallis non-parametric ANOVA, Median test, and Spearman rank correlation were performed to test whether the four categorized relative distance groups differ in the distribution of pairwise beta-diversity among trees. A Mann-Whitney U-test was used to test whether beta-diversity differed among pairs of trees belonging to the same or to different species. In additiona, individual correlation using Spearman rank correlation, as well as multiple regression were applied to assess relationships between lichen species richness and area cover and environmental parameters. The relationship of lichen species richness vs.

area cover was explored using non-linear estimation techniques with least-squares regression (CÁCERES *et al.* 2007b).

To compare the effect of different sampling methods on the proportion of lichen species with different parameters (CÁCERES *et al.* 2007c), for each of the distribution categories the relative proportion of species with different combined scores of lichen parameters (CS = 0, 1, 2, 3, 4) was calculated, and a Chi-Square test of observed versus expected frequencies was applied to test for significant differences in relative proportion of scores between categories. The main differences among the employed sampling methods are listed bellow on Table 1.

Table 1. Comparison of three sampling techniques to assess lichen species richness.

Sampling parameters	Non-quantitative opportunistic sampling (method I)	Repetitive non-quantitative opportunistic sampling (method II)	Quantitative transect sampling (method III)
Selection of phorophytes	Subjective	subjective (refined)	systematic
Phorophytes per site	≈ 50–100	≈ 150	≈ 50
Selection of lichen specimens	visual in situ	visual in situ (refined)	sample presence
Lichen specimens per site	100–200(–300)	≈ 450	≈ 550
Lichen specimens per	≈ 1–5 (∅ 2)	≈ 1–10 (∅ 3)	≈ 1–45 (∅ 11)
Identification of species	Selective	selective (refined)	all

2.3. Results and Discussion

2.3.1 Diversity

a) Taxonomic composition

A total of 456 species of corticolous crustose and microfoliose lichens are reported from the states of Rio Grande do Norte, Paraiba, Pernambuco, Alagoas and Sergipe in northeastern Brazil, based on more than 2,700 collections made at 22 localities representing the three major vegetation types, coastal Atlantic rainforest or Zona da Mata (Mata Atlântica), Brejos de Altitude, and Caatinga, as well as the transitional Agreste region (CÁCERES 2007). Of the 456 species, 426 were identified: 370 could be identified to genus and species level,

while further 35 were tentatively identified to species level and 21 species could not be named to species level due to lack of critical revisions of the corresponding genera. A further 30, sterile species were recognized as distinct taxa due to morphological, anatomical, and chemical features, but could not be named to genus and species level due to lack of critical characters; these taxa are not treated here in detail.

The following 18 species are described as new: *Aciculopsora cinerea* Cáceres & Lücking spec. nova, *Bacidina digitalis* Cáceres & Lücking spec. nova, *B. multiseptata* Cáceres & Lücking spec nova, *Calopadia bonitensis* Cáceres & Lücking spec. nova, *Cryptothecia subcandida* Cáceres & Lücking spec. nova, *Diorygma alagoense* Cáceres & Lücking spec. nova, *Echinoplaca caruaruensis* Cáceres & Lücking spec. nova, *Enterographa chiodectonoides* Cáceres & Lücking spec. nova, *E. subquassiaecola* Cáceres & Lücking spec. nova, *Graphis pernambucoradians* Cáceres & Lücking spec. nova, *G. pilarensis* Cáceres & Lücking spec. nova, *G. stellata* Cáceres & Lücking spec. nova, *Malcolmiella atlantica* Cáceres & Lücking spec. nova, *M. badimioides* Cáceres & Lücking spec. nova, *M. flavo-pustulosa* Cáceres & Lücking spec. nova, *Phaeographis rubrostroma* Cáceres & Lücking spec. nova, *Plectocarpon syncesioides* Cáceres & Lücking spec. nova, and *Sarcographa fissu-rinoides* Cáceres & Lücking spec. nova.

In addition, the following 14 new combinations are proposed: *Arthonia andamanica* (Makhija & Patw.) Cáceres & Lücking comb. nova, *Bacidia fluminensis* (Malme) Cáceres & Lücking comb. et stat. nova, *Chapsa leprocarpoides* (Hale) Cáceres & Lücking comb. nova, *C. punicea* (Müll. Arg.) Cáceres & Lücking comb. nova, *C. sublilacina* (Ellis & Everh.) Cáceres & Lücking comb. nova, *C. velata* (Müll. Arg.) Cáceres & Lücking comb. nova, *Graphis parallela* (Müll. Arg.) Cáceres & Lücking comb. nova, *Malcolmiella furfurosa* (Tuck. ex Nyl.) Cáceres & Lücking comb. nova, *M. fuscella* (Müll. Arg.) Cáceres & Lücking comb. nova, *M. gyalectoides* (Vain.) Cáceres & Lücking comb. nova, *M. hypomela* (Nyl.) Cáceres & Lücking comb. nova, *M. leptoloma* (Müll. Arg.) Cáceres & Lücking comb. nova, *M. perisidiata* (Malme) Cáceres & Lücking comb. et stat. nova, and *M. polycampia* (Tuck.) Cáceres & Lücking comb. nova.

Most of the listed species are new records for the study area in northeastern Brazil, mounting up to more than 400 taxa. Including previous reports of macrolichens and saxicolous, terricolous, and foliicolous lichens (XAVIER FILHO & MARIZ 1970; XAVIER FILHO & KUROKAWA 1971; BEZERRA *et al.* 1973; XAVIER FILHO 1979; AHTI *et al.* 1993; LÜCKING *et al.* 1999a, b; AHTI 2000; CÁCERES *et al.* 2000) the total number of species now known from

the area amounts to about 700. The 456 species found in the present study comes close to the initially estimated 500 species, but the relatively low number of species in certain groups, such as *Anisomeridium*, *Arthopyrenia*, *Lithothelium*, and *Polymeridium*, indicates that more corticolous crustose lichens will be found with further inventories, especially including the more remote Brejos de Altitude, and so the actual number of species in this group is probably closer to 600. More than 200 foliicolous lichens were reported for the area (LÜCKING *et al.* 1999a; AHTI 2000; CÁCERES *et al.* 2000), which results in the rather curious situation that the bulk of lichen diversity known from northe-astern Brazil are corticolous and foliicolous crustose taxa, while foliose and fruticose macrolichens, as well as saxicolous species, are undercollected.

The identified species comprise a number of 115 genera, distributed in 32 families, 12 orders, and 5 classes of Ascomycota and Basidiomycota (Table 2).

Table 2. Systematic arrangement and number of species per genus, family, and order, of the corticolous crustose and microfoliose lichens found in the present study. The classification follows JAMES et al. (2006), SPATAPHORA *et al.* (2006), and MIADLIKOSWKA *et al.* (2006).

Basidiomycota (Agaricomycotina)	***Traponora*** (1 species)
Agaricomycetes	***Vainionora*** (1 species)
Agaricomycetidae	Pilocarpaceae (17 species)
Atheliales (1 species)	***Bapalmuia*** (3 species)
Atheliaceae (1 species)	***Byssoloma*** (4 species)
Dictyonema (1 species)	***Calopadia*** (6 species)
Ascomycota (Pezizomycotina)	***Fellhanera*** (2 species)
Incertae sedis	***Lasioloma*** (1 species)
Mycocaliciales (1 species)	***Tapellaria*** (1 species)
Sphinctrinaceae (1 species)	Ramalinaceae (20 species)
Sphinctrina (1 species)	***Aciculopsora*** (1 species)
Arthoniomycetes	***Bacidia*** (3 species)
Arthoniomycetidae	***Bacidina*** (6 species)
Arthoniales (72 species)	***Bacidiopsora*** (2 species)
Arthoniaceae (37 species)	***Phyllopsora*** (6 species)
Arthonia (14 species)	***Psorella*** (1 species)
Arthothelium (3 species)	***Squamacidia*** (1 species)
Coniocarpon (3 species)	Stereocaulaceae (1 species)
Cryptothecia (11 species)	***Lepraria*** (1 species)
Helminthocarpon (1 species)	Teloschistales (22 species)
Herpothallon (5 species)	Letrouitiaceae (3 species)
Chrysothrichaceae (1 species)	***Letrouitia*** (3 species)
Chrysotrix (3 species)	Physciaceae (19 species)
Roccellaceae (34 species)	***Baculifera*** (2 species)
Bactrospora (3 species)	***Cratiria*** (1 species)
Chiodecton (1 species)	***Dirinaria*** (6 species)
Cresponea (4 species)	***Hafellia*** (4 species)
Dichosporidium (2 species)	***Heterodermia*** (1 species)
Enterographa (6 species)	***Physcia*** (2 species)

Lecanactis (1 species)
Lecanographa (1 species)
Opegrapha (12 species)
Plectocarpon (1 species)
Sagenidiopsis (1 species)
Sclerophyton (1 species)
Syncesia (2 species)
Dothideomycetes
Pleosporales (1 species)
Arthopyreniaceae (1 species)
Arthopyrenia (1 species)
Incertae sedis
Monoblastiaceae (10 species)
Anisomeridium (5 species)
Caprettia (1 species)
Megalotremis (1 species)
Musaespora (3 species)
Strigulaceae (4 species)
Strigula (4 species)
Trypetheliaceae (20 species)
Arthitrypethelium (1 species)
Astrothelium (5 species)
Bathelium (2 species)
Cryptothelium (1 species)
Laurera (2 species)
Lithothelium (1 species)
Polymeridium (1 species)
Pseudopyrenula (2 species)
Trypethelium (6 species)
Eurotiomycetes
Chaetothyriomycetidae
Pyrenulales (22 species)
Pyrenulaceae (22 species)
Anthracothecium (2 species)
Celothelium (1 species)
Pyrenula (19 species)
Verrucariales (1 species)
Verrucariaceae (1 species)
Flakea (1 species)
Lecanoromycetes
Candelariomycetidae
Candelariales (1 species)
Candelariaceae (1 species)
Candelaria (1 species)
Lecanoromycetidae
Lecanorales (59 species)
Brigantiaeaceae (1 species)
Brigantiaea (1 species)
Catillariaceae (2 species)
Catillaria (2 species)
Lecanoraceae (18 species)
Crocynia (2 species)
Haematomma (2 species)
Lecanora (9 species)
Maronina (1 species)
Pyrrhospora (2 species)
Pyrine (1 species)
Rinodina (1 species)
Stigmatochroma (1 species)
Incertae sedis
Lopezaria (1 species)
Peltigerales (2 species)
Coccocarpiaceae (2 species)
Coccocarpia (2 species)
Ostropomycetidae
Ostropales (165 species)
Gomphillaceae (5 species)
Aderkomyces (1 species)
Echinoplaca (3 species)
Tricharia (1 species)
Graphidaceae (76 species)
Anomomorpha (1 species)
Carbacanthographis (3 species)
Diorygma (5 species)
Dyplolabia (2 species)
Fissurina (6 species)
Glyphis (3 species)
Graphis (31 species)
Hemithecium (2 species)
Phaeographis (15 species)
Platygramme (1 species)
Platythecium (1 species)
Sarcographa (5 species)
Thalloloma (1 species)
Coenogoniaceae (18 species)
Coenogonium (18 species)
Gyalectaceae (2 species)
Cryptolechia (1 species)
Ramonia (1 species)
Myeloconidaceae (1 species)
Myeloconis (1 species)
Phlyctidaceae (1 species)
Phlyctella (1 species)
Porinaceae (21 species)
Porina (19 species)
Trichothelium (2 species)
Stictidaceae (1 species)
Stictis (1 species)
Thelenellaceae (2 species)
Aspidothelium (1 species)
Thelenella (1 species)
Thelotremataceae (38 species)
Acanthotrema (1 species)
Ampliotrema (2 species)
Chapsa (13 species)
Myriotrema (5 species)
Ocellularia (13 species)
Stegobolus (3 species)
Thelotrema (1 species)
Pertusariales (8 species)
Pertusariaceae (8 species)
Ochrolechia (1 species)
Pertusaria (7 species)

b) Alpha-diversity [α]

Alpha-diversity is more commonly used nowadays for the diversity of a habitat. CÁCERES *et. al* 2007b considered the alpha-diversity as the diversity of a single collecting site, and so it was calculated as the number of lichen species per site. CÁCERES *et al.* 2007c also calculated the alpha-diversity between analysed phorophytes, considering the lichen diversity in each microsite.

Few studies are available in which lichen diversity, especially microlichens, was assessed for tropical rainforest vegetation. Comparisons of the numbers found in this study with other sites in the tropics are therefore difficult. Analysis of other tropical localities yielded a large range of different numbers: thus, montane rain forest sites in Costa Rica, Colombia and Ecuador had 32–51 macrolichen and 29 microlichen species per site (WOLF 1993a; HOLZ & GRADSTEIN 2005; NOESKE 2004), but in these cases, microlichens were left undetermined in the first two cited studies and determined mostly to genus level only in the last study. Also, the vegetation is quite different from the relatively drier and warmer northeastern Atlantic rainforest, and is generally expected to have higher lichen biomass but fewer species, especially microlichens. Lowland sites were investigated in Venezuela by KOMPOSCH & HAFELLNER (1999, 2000, 2002), in Guyana by CORNELISSEN & TER STEEGE (1989) and in French Guiana by MONTFOORT & EK (1990), and these workers reported 19–33 species of macrolichens per site but again left most of the microlichens unidentified. Microlichens were mostly determined to morphospecies level only, which suggests that the real species numbers are higher.

As the outcome of a major inventory on 22 localities in north-eastern Brazil (CÁCERES 2007; CÁCERES et. al 2007a), it was found that the number of species per site varied from three to 99 (Figure 2). The site with the highest number of species was the repetitively sampled RPPN Fazenda São Pedro in the state of Alagoas. The highest species numbers for opportunistically sampled sites were found for those representing Brejos de Altitude, which contributed 84 (Brejo dos Cavalos) and 73 species (Parque Municipal de Bonito), respectively. Sites within the Zona de Mata had slightly lower species numbers, the richest being the Refúgio Ecológico Charles Darwin (71) and the Estação Ecológica de Gurjaú (60) in the state of Pernambuco. The small rainforest remnant at Barragem near Gurjau had only eight taxa. The two Zona da Mata fragments situated at higher altitudes, Serra de Itabaiana and Fazenda São José, had 5–20 taxa. The three sites of exposed secondary vegetation within the Zona da Mata, namely the RPPN Rosa do Sol, the UFPE Campus, and the exposed

secondary vegetation at Gurjaú, showed little variation in the number of species (16–19), while only eight taxa were found at the exposed secondary vegetation near Brejo dos Cavalos. Only one site, Estação Ecológica de Tapacurá, was located in the transitional Agreste region; it had 22 species. Within the Caatinga, the number of species varied from 23 to 54 per site, with the largest number reported for the most conserved Caatinga vegetation at the IPA in Caruaru. The two sites representing exposed secondary Caatinga area, Garanhuns and the exposed secondary vegetation at the IPA, had 3–12 species.

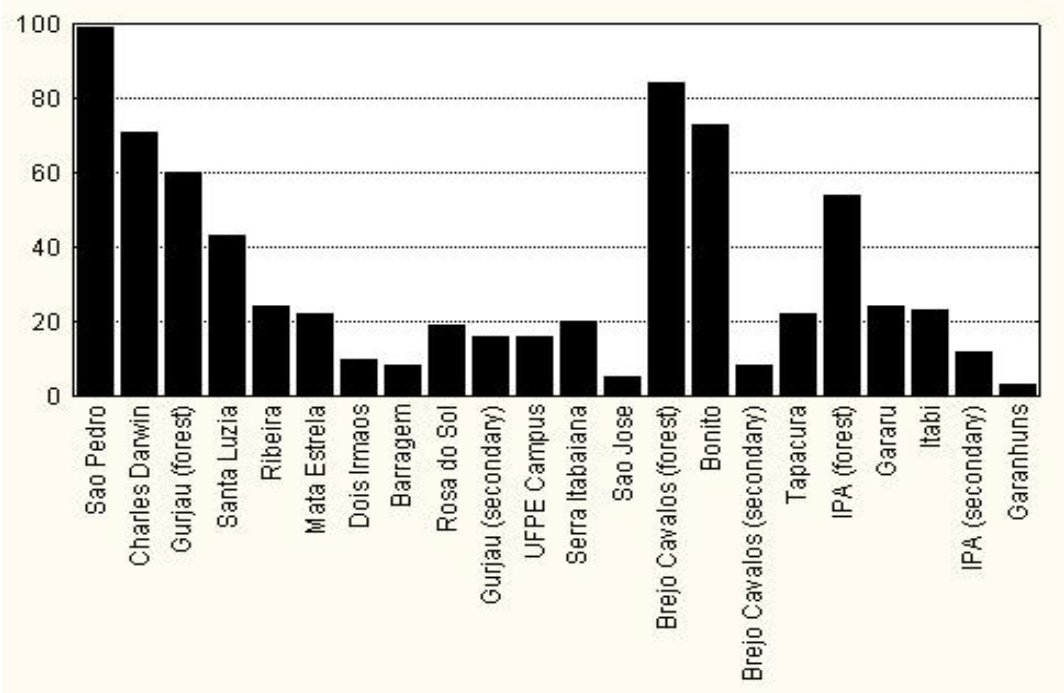

Figure 2 – Alpha-diversity expressed here by the number of lichen species per site

The alpha-diversity calculated between microsites, which meant the variation on the number of lichen species per phorophyte tree (CÁCERES *et. al*. 2007c), was done as a result of an ecological study at the RPPN Fazenda São Pedro, where a quantitative and non-opportunistic sampling method was used (CÁCERES *et al*. 2007c). In this case, the number of taxa per phorophyte tree varied between two and 24 species.

c) Beta-diversity (β)

Here β-diversity is defined as the dissimilarity between sites, and it was computed using the complement of Sorensen's coefficient of similarity already mentioned above. Beta-diversity was also estimated between macrosites, i.e. the three vegetation types in northeastern Brazil

(CÁCERES *et. al* 2007b), as well between microsites such as the 47 phorophytes trees in RPPN Fazenda São Pedro, Alagoas state, Brazil (CÁCERES *et al.* 2007c).

Beta-diversity (Sørensen dissimilarity) in lichen species composition between any two sites from the whole study area in NE Brazil was relatively high, with values ranging between 0.41 and 1.00 and a mean of 0.79 (Table 3). In other words, any two sites shared between 0% and 59% of the species only, with a mean of 21%. When comparing Zona da Mata sites only, the smallest dissimilarity value between any two sites was 0.45, which means that a maximum of 55% of the species was shared between any two sites and for all pairwise comparisons there were only 22% of the species in common on average. The two sites representing Brejos de Altitude had a dissimilarity of 0.56, meaning that they shared 44% of the species. With respect to the three collecting sites located within the Caatinga, the smallest dissimilarity was 41% and the highest 83%, which means only 17–59% of the species were shared between sites. Although mean similarity was highest between Brejos de Altitude sites and lowest between Zona da Mata sites, the differences were not statistically significant (Kruskal-Wallis ANOVA).

Table 3. Sørensen dissimilarity and percentage similarity between sites (ranges and mean), arranged according to the three main vegetation types and their anthropogenic variations.

Vegetation type	Dissimilarity (range)	Dissimarity (mean)	Similarity (range)	Similarity (mean)
Zona da Mata (0–100 m)	0.45–1.00	0.78	0–55%	22%
Zona da Mata (0–100 m exposed)	0.67–0.85	0.75	15–33%	25%
Zona da Mata (300–500 m)	—	1.00	—	0%
Brejos de Altitude	—	0.56	—	44%
Caatinga	0.41–0.83	0.64	17–59%	36%
Caatinga (exposed)	—	0.72	—	28%
All sites	0.41–1.00	0.79	0–59%	21%

When comparing sites across the three main vegetation types, the dissimilarity values across Zona da Mata versus Brejos de Altitude sites were found to be relatively high, with an average value of 0.77 or 23% of shared species (Table 4). Differences in species composition across Zona da Mata versus Caatinga were even more pronounced, with dissimilarity values

averaging 0.92. Similarly high dissimilarity values were found across sites representing Brejos de Altitude and Caatinga. While the average similarity across Zona da Mata versus Brejos de Altitude is not different from the average between Zona da Mata sites (23% vs. 22%) and the average for all sites (21%), similarity across Zona da Mata and Brejos de Altitude versus Caatinga is significantly lower (8% vs. 22%, 44%, and 36%, respectively). This indicates that Caatinga lichen communities are more distinct from Zona da Mata and Brejos de Altitude communities than Brejos de Altitude from Zona da Mata communities.

Table 4. Sørensen dissimilarity and percentage similarity between sites (ranges and mean), comparing sites across the three main vegetaiton types.

Vegetation type	Dissimilarity (range)	Dissimilarity (mean)	Similarity (range)	Similarity (mean)
Zona da Mata vs. Brejos de Altitude	0.57–1.00	0.77	0–43%	23%
Zona da Mata vs. Caatinga	0.69–1.00	0.92	0–31%	8%
Caatinga vs. Brejos de Altitude	0.87–0.98	0.92	2–13%	8%
All sites	0.41–1.00	0.79	0–59%	21%

Beta-diversity was relatively high on average among the 47 tree samples during the ecological study at RPPN Fazenda São Pedro, with more than 60% of the pairwise comparisons showing values higher than 0.9, that is 90% or more different species, and only 10% having values 0.5 and lower, that is sharing 50% or more of the species among samples. Beta-diversity did not differ among categorical distance groups, although there is a very slight tendency for values among trees of the same group (distance group 0) being slightly lower. However, beta-diversity values were highly significantly lower among samples belonging to the same tree species ($p < 0.001$) than among samples belonging to different tree species.

The beta-diversity between the three main vegetation types analyzed recently (CÁCERES et al. 2007b) can also be illustrated as follow (Figure 3):

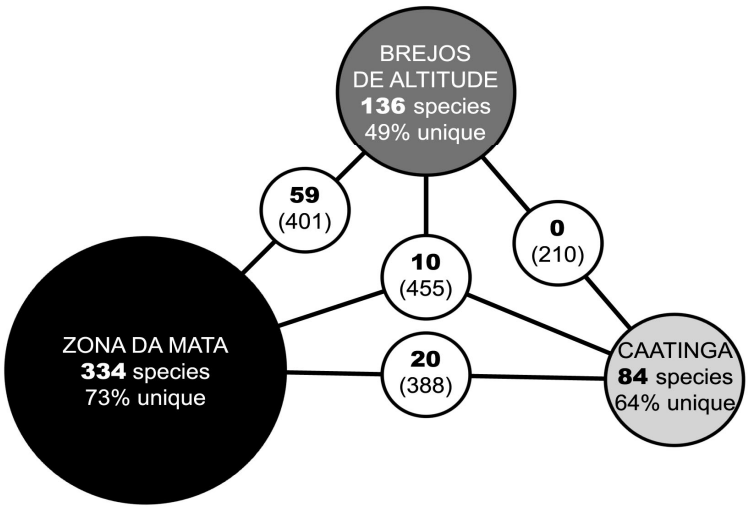

Figure 3. Number of lichen species unique for and shared between each of the three main vegetation types. Numbers in boldface in white circles indicate number of shared species between vegetation types, and numbers in parentheses below indicate total number of species for combined vegetation types.

d) Gamma-diversity [γ]

Gamma-diversity is treated here as the inclusive diversity of the entire habitat types within an area, which means in other words regional diversity. Thus the gamma-diversity was calculated as the total number of species per vegetation type (CÁCERES et al. 2007b) and not for the whole study area.

When combining all sites within each of the three main vegetation types and their anthropogenic variations, the Zona da Mata understory sites yielded a total of 281 species, being the most diverse of the three vegetation zones altogether (Figure 4). For the exposed secondary Zona da Mata sites and the higher altitude Zona da Mata forests, 43 and 25 taxa were found in total, and the combined number for the Zona da Mata sites was 334. The Brejos de Altitude localities represented the second most diverse region of the study area, with a total of 136 species. The three sites representing Caatinga vegetation comprised a total of 79 species, and the two exposed secondary Caatinga sites yielded 15 taxa, totalizing 84 species for all five Caatinga sites.

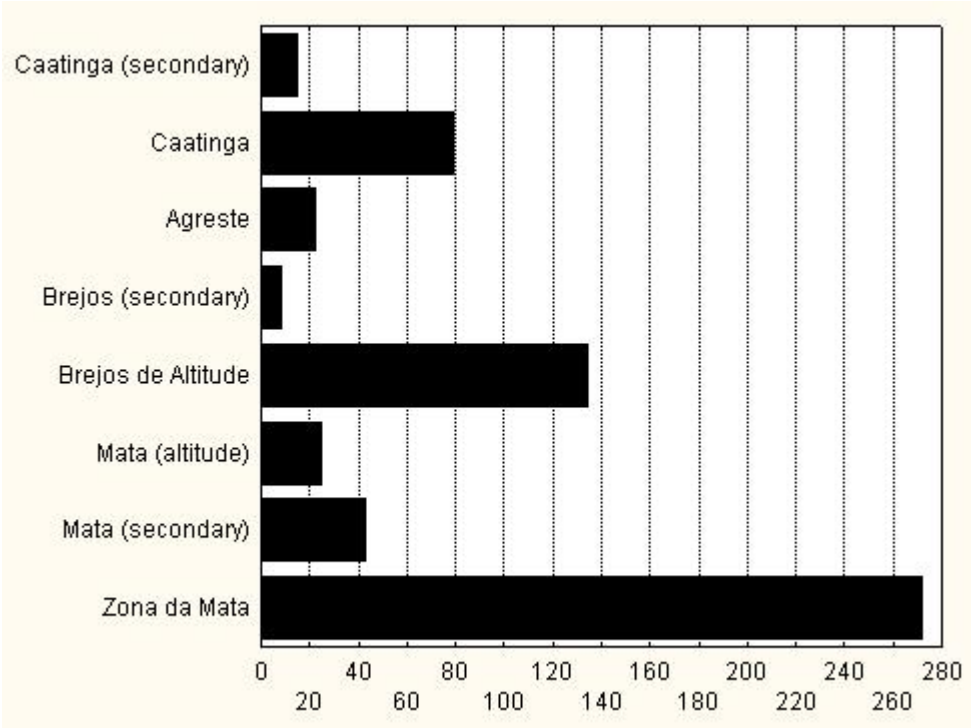

Figure 4. Combined number of lichen species for the three main vegetation types and their anthropogenic variations.

e) Appropriate sampling method to estimate lichen diversity

Correct or appropriate sampling is a precondition for an accurate estimation of alfa-diversity (CÁCERES et al. 2007c). A total of 456 species of corticolous crustose and microfoliose lichens were found in the study area as whole (CÁCERES 2007), combining the results of all three sampling techniques.

The number of species per site varied strongly, but by far the highest number was found within the transect (method III) at RPPN Fazenda São Pedro (150 species) and the second highest number within the repetitively collected area (method II), also at RPPN Fazenda São Pedro, with 99 species (CÁCERES et al. 2007c). The localities with the highest number of species found by opportunistic sampling (method I) were the two Brejos de Altitude (Brejo dos Cavalos, Bonito), with 84 and 73 species, respectively. Apart from RPPN Fazenda São Pedro, the highest number for a Zona da Mata site was 71 species at Refúgio Ecológico Charles Darwin. The average number of species per site for the 22 localities studied by opportunistic sampling was 30% of the total number found at the repetitively sampled RPPN Fazenda São Pedro and 20% of the total number found within the transect. The total number of species at RPPN Fazenda São Pedro, combining repetitive and quantitative sampling was

205, and 76 were only found within the transect. About 17% of the recorded species are thus unique to the transect at RPPN Fazenda São Pedro and were not found through opportunistic sampling within any of the other localities. The number of lichen species per sampled phorophyte tree was by far highest within the transect (3.19) and much lower (0.39–0.66) in the other localities, whereas the number of lichen species per collected specimen was about the same (0.19–0.22) for sampling methods I and II and slightly higher (0.27) for method III.

Most of the lichen species had combined lichen parameter scores ranging between CS = 1 and CS = 3, while species with combined scores CS = 0 and CS = 4 were much fewer in number. The relative proportion of scores was significantly different from the overall proportions for four of the eight distribution categories. Categories A–C (chiefly species found by opportunistic sampling) had significantly higher proportions of species with combined scores CS = 2, 3, and 4 ($p < 0.05$ for A and B, $p < 0.001$ for C), while category G (species found by quantitative sampling) had significantly higher proportions of species with combined scores CS = 0 and 1 ($p < 0.001$). In other words, the proportion of species which are abundant, conspicuous, fertile, and/or distinctive, is higher among taxa found by opportunistic sampling, while the proportion of rare, inconspicuous, sterile, and/or cryptic species is higher among those taxa found by quantitative sampling. The overall proportion of species with combined scores CS = 0 or 1 for RPPN Fazenda São Pedro (collected by methods II and III) is 84 out of 205 or 41%, while the overall proportion for the 22 localities collected through opportunistic sampling (method I) is 56 out of 301 or 19% only.

This analyses can also be used to estimate total lichen species richness for a given site, or in other words to estimate the alpha-diversity. Based on the species numbers resulting from opportunistic sampling, RPPN Fazenda São Pedro can be considered a moderately diverse site, since it ranged third with 53 species (first visit only) after Charles Darwin (71 species) and Gurjaú (60 species). The total number of species found at RPPN Fazenda São Pedro, however, combining all three sampling methods, was 205, roughly four times the number found by one-time opportunistic sampling. If the factor 4 is applied to the other sampled localities, the total number of species is estimated to ≈ 280–330 per site for the supposedly richest sites Charles Darwin, Bonito, and Brejo dos Cavalos. These numbers are identical to the well-supported estimates for sites in Costa Rica and Venezuela, with about 300 corticolous lichen species per site (KOMPOSCH & HAFELLNER 1999, 2000, 2002, MONCADA *et al.* in prep.; LIZANO *et al.* in prep.) and also show that the Atlantic rainforest in northeastern Brazil supports high lichen diversity inspite of its relatively dry conditions.

2.3.2. Phenotypic characters and ecology

a) Criteria for elaboration of the identification key

In order to assess the biodiversity of specific sites, habitats, or of an entire region as well, the investigator has to be able to at least separate the numerous collected specimens of the studied organisms in different categories and eventually different species. For this purpose, one of the most important tools is the identification keys and descriptions of taxa from previous works undertaken in similar habitats. Once the spectrum of the organismic diversity of that particular area, region or country is assessed the catalogation and elaboration of an identification key for the species reported locally is crucial for the development of further studies concerning the same organisms from that area.

When talking about microlichens and microfoliose lichens from north-eastern Brazil (CÁCERES 2007), an artificial group of lichenized fungi only distinguished by the growth form, the most important characters for the separation of the orders, families and genera are the most conspicuous ones, which concern to the reproductive structures, such as: presence or absence of fruit bodies, type of fruit bodies (if perithecioid or apothecioid), presence, absence and type of aphotecial margin, etc., to name a few.

Traditionally, the combination of phenotypical characthers is responsible for the identification of the lichen species, and for some groups and genera of lichenized fungi there are always some more relevant charachters than others. For example, after a recent study of the Graphidaceae by STAIGER (2002) it is considered that the presence or not of carbonization in the ascomata, if totally or partially carbonized, will distinguish already some new genera within that family. For the genus *Cresponea*, for instance, the separation of infra-generic taxa will be done by ascospores size and septation, as well as by the size of the apothecia. Also the secondary chemistry of medullary and cortical substances is essencial for the separation of species on some genera such as *Herpothalon* and *Cryptothecia* (CÁCERES *et al.* 2007c).

b) Distribution of diagnostic characters in each vegetation zone

As one of the results of the comparison between the lichen compositions of the three vegetation types, it was observed that some taxa can be considered as indicative of that particular habitat, according to the frequency data (CÁCERES *et al.* 2007b). There was then particular interest to note whether the proportions of the systematic units among these taxa

were of significat statiscal value.

Among the lichen species unique to the Zona da Mata, there is a higher proportion of the subclasses *Arthoniomycetidae* (*Arthoniales*: *Arthoniaceae*, *Roccellaceae*) and *Chaetothyriomycetidae* (*Pyrenulales*: *Pyrenulaceae*), as well as of the families *Porinaceae* and *Thelotremataceae* (Table 5), compared to the overall proportions of these taxa among all lichen species. Because of the aforementioned explanation, this difference is not significant, however (Chi-Square test). The Brejos de Altitude have a significantly higher proportion of *Dothideomycetiae* (*Trypetheliaceae*) and *Ostropomycetidae* (*Ostropales*: *Gomphillaceae* and *Graphidadeae*), as well as *Pilocarpaceae* ($p < 0.05$). *Lecanoromycetidae* (*Lecanorales*: *Lecanoraceae*; *Teloschistales*: *Physciaceae*), as well as *Pertusariales* (*Pertusariaceae*) are the predominant subclasses, orders, and families found within the Caatinga sites ($p < 0.001$).

The predominant thallus type is squamulose for the Zona da Mata, byssoid for the Brejos de Altitude, and microfoliose for the Caatinga, but the observed differences are significant for the latter only (Table 5). Lichens in the Zona da Mata frequently have trentepohlioid photobionts ($p < 0.05$), while those in the Caatinga are associated with chlorococcoid photobionts ($p < 0.001$). Vegetative dispersal by isidia is more common within the Zona da Mata, while Caatinga lichens more frequently disperse by soredia, but the difference is not significant at the 5% level (Table 5). The predominant ascoma types are perithecia for the Zona da Mata, lirellae for the Brejos de Altitude, and apothecia and stromata for the Caatinga, but the patterns are not significant either. Ascospores are predominantly transversely septate and/or narrow in lichens of the Zona da Mata (not significant), thick-walled or muriform ($p < 0.05$) and hyaline in those of the Brejos de Altitude, and megalosporous, non-septate and/or brown (all $p < 0.05$) in Caatinga species. Both Zona da Mata and Brejos de Altitude have no predominant secondary substances, except for psoromic acid in the first, but Caatinga lichens show a highly significant predominance of atranorin, lichexanthone and other xanthones, as well as pulvinic acid derivates, as cortical substances, and norstictic acid as medullary substance.

Table 5. Differences in the relative proportion of lichen species belonging to different higher taxa and showing different morphological, anatomical, and chemical features, between the three main vegetation types (Chi-Square test). Predominant taxa and features are indicated in bold face. TTT = highly significant ($p < 0.001$), T = significant ($p < 0.05$), (T) = tendential ($p < 0.1$), and (–) = not significant.

	Zona da Mata	p-level	Brejos de Altitude	p-level	Caatinga	p-level
Subclass	*Arthonio-mycetidae* *Chaetothyrio-mycetiae*	(–)	*Dothideo-mycetidae* *Ostropo-mycetidae*	T	***Lecanoro-mycetidae***	T
Order/Suborder	*Arthoniales* *Ostropales* *Pyrenulales*	(–)	*Ostropales*	T	*Lecanorales* ***Pertusariales*** ***Teloschistales***	TTT
Family	*Arthoniaceae* *Porinaceae* *Pyrenulaceae* *Roccellaceae* *Thelotrematacea e*	(–)	***Gomphillaceae*** *Graphidaceae* ***Pilocarpaceae*** ***Trypetheliacea e***	T	***Lecanoraceae*** ***Pertusariaceae*** ***Physciaceae***	TTT
Thallus type	squamulose	(–)	byssoid	(–)	**microfoliose**	(T)
Photobiont	**trentepohlioid**	T	[none]	(–)	**chlorococcoid**	TTT
Ascoma type	perithecia	(–)	lirellae	(–)	apothecia **stromata**	(–)
Vegetative dispersal	isidia	(–)	[none]	(–)	**soredia**	(T)
Ascospore type	[none]	(–)	thick-walled	(–)	**megalosporou s**	T
Ascospore septa	transverse	(–)	**muriform**	T	**non-septate**	T
Ascospore shape	narrow	(–)	broad	(–)	broad	(–)
Ascospore color	[none]	(–)	hyaline	(–)	**brown**	T
Chemistry	nil psoromic acid	(–)	**nil**	(–)	**atranorin** **lichexanthone** **norstictic acid** pulvinic acids xanthones	TTT

c) Scores – inconspicuous x conspicuous, abundant x rare, etc.

Apart from the appropriate tools for identifying the studied organisms, an efficient sampling method is extremely important in order to accurately estimate the organismical diversity in any given area. NEWMASTER *et al.* (2003) proposed for example a combination of already well-used methods for a better estimatition of the diversity of bryophites, when dealing with a variation of microhabitats. Similar works have been published as well regarding to lichen species richness estimatives, but on basis only of raw observation and own field experience of the collector. CÁCERES *et. al* (2007c) analysed the results of various field trips and inventories on 22 localities in northeastern Brazil, by applying three distinct sampling methods for corticolous microlichens.

After the completion of the major inventory of corticolous microlichens in the states of Rio Grande do Norte, Paraíba, Pernambuco, Alagoas and Sergipe (CÁCERES 2007), it was demonstrated that the chosen sampling technique was crucial for the estimation of the lichen specien richness of that area (CÁCERES *et. al* 2007c). On a raw scale, considering only localities with comparable ecological parameters, opportunistic sampling (method I) recovered only about one third the number of species on average than repetitive sampling (method II). On the other hand, quantitative sampling (method III) recovered more than five times the number of species than opportunistic sampling on average and 50% more species than repetitive sampling. This difference is explained by the idea that with the quantitative transect method, one is forced to collect specimens that one would usually not collect by means of visible inspection only, because they are either rare, inconspicuous, sterile, and/or cryptic, a notion that is confirmed by the significantly higher proportion of such species with the quantitative transect method, while the non-quantitative opportunistic method recovers a higher proportion of abundant, conspicuous, fertile, and/or distinctive taxa.

For each species, the four binary codes were added to a combined score CS, ranging from 0 (species rare, inconspicuous, sterile, and cryptic) to 4 (species abundant, conspicuous, fertile, and distinctive). Since the individual states for each parameter are independent of each other, any combination of codes is possible, for a total of $2^4 = 16$ combinations (Table 6). Examples for combined score = 0 include all the sterile taxa (30 out of a total of 456) that were recognized as distinct species based on their morphology, anatomy, and chemistry, but could not be named due to the lack of critical systematic characters. Examples for combined score CS = 4 include *Chapsa dilatata*, *Cryptothecia striata*, *Dichosporidium nigrocinctum*,

Glyphis cicatricosa, *Graphis chrysocarpa*, *Helminthocarpon leprevostii*, *Hemithecium chrysentheron*, *Lecanora caesiorubella*, *Lecanactis epileuca*, *Letrouitia domingensis*, *Malcolmiella badimioides*, *Maronina multifera*, *Ocellularia bahiana*, *Ochrolechia africana*, *Phaeographis haematites*, *Pyrenula mamillana*, *Sarcographa labyrinthica*, and *Trypethelium tropicum*.

The most striking examples of cryptic species that were recovered by applying a combinations of sampling techniques are the genera *Cryptothecia* and *Herpothallon*, whose species are frequently sterile and form white or pale green crusts that are easily seen but which do not usually call the attention of the opportunistic collector since they appear to belong to the same species and are not very promising candidates for successful identification. A large number of specimens of these two genera were collected within the transect, and microscopical and chemical examination revealed that the number of cryptic species was unusually high: what appeared as two different taxa in the field turned out to represent no less than nine different species after careful study in the laboratory. Other examples include the genera *Bacidina*, *Coenogonium*, *Cryptolechia*, *Enterographa*, *Fellhanera*, *Ramonia*, and *Stictis*, which are unlikely to be collected by opportunistic sampling due to their small and inconspicuous thalli and fruit bodies. Species of *Coenogonium*, as well as *Graphis* and several pyrenocarpous genera (*Anisomeridium*), are known to contain a high number of cryptic species which cannot be identified in the field (HARRIS 1995, LÜCKING *et al.* 2007), and also in these genera, quantitative transect sampling is likely to turn out higher species numbers than opportunistic sampling.

Table 6. Calculation of combined score for selected lichen parameters.

Abundance	Conspicuous-ness	Fertility	Distinctive-ness	Combined score CS	Example
0	0	0	0	**0**	*Malcolmiella polycampia*
0	0	0	1	**1**	*Ocellularia* sp. (red soralia)
0	0	1	0	**1**	*Bactrospora macrospora*
0	1	0	0	**1**	*Herpothallon sp.*
1	0	0	0	**1**	*Porina conspersa*
0	0	1	1	**2**	*Bacidina penicillata*
0	1	0	1	**2**	*Cryptothecia punctosorediata*
1	0	0	1	**2**	[no species found]

0	1	1	0	**2**	*Graphis striatula*
1	0	1	0	**2**	*Arthopyrenia chinchonae*
1	1	0	0	**2**	*Chryothrix xanthina*
0	1	1	1	**3**	*Haematomma leprarioides*
1	0	1	1	**3**	*Chapsa alborosella*
1	1	0	1	**3**	*Herpothallon rubrocinctum*
1	1	1	0	**3**	*Cresponea leprieurii*
1	1	1	1	**4**	*Laurera megasperma*

2.3.3. Conservation aspects

The conservation of tropical forests in general and now more specifically Brazil's Atlantic forest has gradually become a very important issue in the present days (MYERS *et al.* 2000). Over the past few years many studies have been published about the diversity of higher plants and vertebrates naturally occurring in this so endangered ecossystem (MELO SANTOS *et al.* 2006; PONTES *et al.* 2006). As already mentioned above, two of the three major neotropical rainforest blocks are located in Brazil, the largest being the Amazon and the other the Atlantic rainforest or Mata Atlântica. This makes Brazil the country with the largest amount of tropical rainforests on the globe. The Atlantic rainforest is one of the most endangered biomes in the world. It is considered one of the five most important biodiversity 'hotspots' worldwide (MYERS *et al.* 2000), being one of the biologically richest yet most threatened regions.

CÁCERES *et al.* (2000) a in a survey of the foliicolous lichen biota on remnants of Atlantic rainforest from Pernambuco state, northeastern Brazil observed that the fragmented Atlantic rainforest remnants only conserve a small part of the overall foliicolous lichen diversity and that conservation of larger areas and corridors is needed to maintain high levels of species diversity in this threatened ecosystem. Also, it could be shown that selected logging not only reduces foliicolous lichen diversity but also alters community structure and particularly threatens those communities adapted to light gaps in the forest understory.

In the Brazilian northeast, where the Atlantic rainforest, or Mata Atlântica, is represented mostly by a narrow tropical forest strip along the coast, extending from Rio Grande do Norte to Bahia state (WHITMORE 1990) the estimation of the corticolous lichen biota was recently undertaken by CÁCERES 2007, and almost the same pattern was found comparing to the foliicolous lichens (CÁCERES *et al.* 2000). It was noted that, when comparing the species compositions for example of the investigated sites in the Zona da Mata, where the Atlantic

coastal forest fragments are located, the similarity was relatively low among sites, with an average of about 22 %, being the maximum value of similarity 55%. This means that each small forest fragment of Mata Atlântica, which in NE Brazil occurs in scattered remnants throughout a landscape dominated by agricultural uses, contributes significantly to the lichen species richness as whole in this type of vegetation. In terms of conservation, all of the still remaining Atlantic rainforest patches should be equally considered.

In a smaller scale, the beta-diversity (dissimilarity) between the phorophyte trees in one of the forest fragments studied by CÁCERES *et al.* (2007c) was found to be also relatively high, what means that each single tree holds a distinct lichen composition, which enforces the question of conservationist approaches for the area. Also, no less than 86% of the species are found to be rar, actually sampled only once or twice at the most. These rare species add a significant component of stochasticity to the data and partly explain the absence of strong community patterns when studying the influence of abiotic factos and phorophytes characters in the formation of lichen communities CÁCERES *et al.* (2007c). It is therefore often suggested to exclude rare species from community ecology analyses (GREIG-SMITH 1978; GAUCH 1982; JONGMAN et al. 1995; MCCUNE & GRACE 2002), but on the other hand they make up a significant component of taxonomic diversity and are indispensable for considerations on conservation of biodiversity.

2.4 Summary

- Collections of crustose and microfoliose corticolous lichens made in a number of 22 localities of Atlantic rainforest, Caatinga and Brejos de Altitudes (caatinga enclaves) in the states of Rio Grande do Norte, Paraiba, Pernambuco, Alagoas, and Sergipe, in northeastern Brazil yielded a total of 450 species. The reported species of corticolous lichens comprise a number of 110 genera, distributed in 32 families, 12 orders, and 5 classes of Ascomycota and Basidiomycota.

- A total of 14 taxa are described here as new to science in the genera *Aciculopsora* (1 species), *Bacidina* (1 species), *Calopadia* (1 species), *Cryptothecia* (1 species), *Enterographa* (2 species), *Graphis* (3 species), *Malcolmiella* (3 species), *Phaeographis* (1 species), and *Plectocarpon* (1 species). In addition, 5 new combi-

nations are proposed in the genera *Chapsa* (13 species) and 7 in the genera *Malcolmiella* (18 species).

- Identification keys to the genera and species of corticolous crustose and microfoliose lichens of northeastern Brazil are provided, with complete checklist and descriptions of new species.

- The comparison between different vegetation types and localities across the study area used the lichen species composition at each site to ordinate and classify sites by applying non-metric multidimensional scaling (NMS) as ordination method and cluster analysis based on Sørensen's coefficient of dissimilarity as classification method.

- The highest dissimilarity was registered between the Atlantic rainforest sites, with an average of 21% and maximum of 55%. The lichen species composition from the Atlantic rainforest sites as a whole compared to the Caatinga sites showed dissimilarity values averaging 0.92 or 8% of shared species. The same value of dissimilarity was found among Caatinga and Brejos de Altitude sites on average.

- The influence of tree bark characteristics and phorophyte species on lichen species composition, richness, and area cover, in a selected fragment of Atlantic rainforest, to assess how tree diversity affects corticolous lichen diversity and the spatial distribution of lichen species within the forest is analyzed.

- Multivariate analysis of sample plots, including non-metric multidimensional scaling (NMS), detrended correspondence analysis (DCA), and canonical correspondence analysis (CCA), and also cluster analysis, indicated subtle patterns of phorophyte preferences among certain lichen species, as well as correlation with environmental parameters, in particular bark pH, degree of bark shedding, and density and size of bark lenticels.

- Individual and multiple correlation also revealed correlations between lichen species richness and area cover on one hand and bark pH (negative), density and

size of bark lenticels (negative), degree of bark shedding (negative), presence of milk sap (positive), and diffuse site factor (positive).

- No distinct lichen communities were detected among the samples, but cluster analysis revealed three main sample groups and six subgroups with slightly different lichen species composition, each one with characteristic indicator species but with highly variable overall species composition.

- It is concluded that community formation in tropical rainforest understory lichens is governed by two main factors, phorophyte bark characteristics and microclimate, but is largely obscured by the stochastic effects of species dispersal and rare species, and also the amount of phorophyte tree diversity.

- It is predicted that phorophyte specificity is best observed in model systems with low tree and low lichen diversity, distinct differences between tree species in terms of bark characteristics, homogeneous population structure, and low microclimatic variation.

- Finally, three different sampling methods were considered on the present study and their efficiency for more accurate estimation of tropical microlichen diversity was tested: (I) one-time non-quantitative opportunistic sampling per site ('opportunistic') for carried out in 21 localities, (II) three-times repetitive non-quantitative opportunistic sampling at a single site ('repetitive'), and (III) quantitative transect sampling at a single site ('quantitative').

- The analysis showed that opportunistic sampling fails to detect rare, inconspicuous, sterile, and/or cryptic species, usually neglected or overlooked in the field. Accordingly, of the 456 lichen species collected and identified across the 22 studied localities, no less than 76 were unique to the quantitatively sampled transect, and the lichen species sampled with this method had a significantly higher proportion of rare, inconspicuous, sterile, and/or cryptic species.

- It is also apparent that it is not the higher number of specimens collected via quantitative sampling that results in a higher number of species, but the method of selection of the specimens, which is subjective and biased towards abundant, conspicuous, fertile and/or distinctive species in opportunistic sampling, but objective and unbiased in quantitative sampling.

2.5 Zusammenfassung

- Die Erhebung krustenförmigen und mikrofolioser rindenbewohnender Flechten an 22 Standorten im Atlantischen Regenwald, Caatinga und Brejos de Altitudes (caatinga Enklaven) in den Staaten Rio Grande do Norte, Paraiba, Pernambuco, Alagoas und Sergipe in Nordost-Brasilien ergab insgesamt 450 Arten. Die registrierten rindenbewohnenden Flechten umfassen 110 Gattungen in 32 Familien, 12 Ordnungen und 5 Klassen der Ascomycota und Basidiomycota.

- Insgesamt 14 Taxa werden hier als neue Arten beschrieben, die den Gattungen *Aciculopsora* (1 Art), *Bacidina* (1 Art), *Calopadia* (1 Art), *Cryptothecia* (1 Art), *Enterographa* (2 Arten), *Graphis* (3 Arten), *Malcolmiella* (3 Arten), *Phaeographis* (1 Art) und *Plectocarpon* (1 Art) angehören. Es werden 5 Neukombinationen in der Gattung *Chapsa* (13 Arten) und 7 in der Gattung *Malcolmiella* (18 Arten) vorgeschlagen.

- Es werden Bestimmungsschlüssel zu den Gattungen und Arten der rindenbewohnenden krustenförmigen und mikrofoliosen Flechten Nordost-Brasiliens mit einer vollständigen Checkliste und Beschreibungen der neuen Arten vorgelegt.

- Zum Vergleich der verschiedenen Vegetationstypen und Standorte innerhalb des Untersuchungsgebietes wurde die Artenzusammensetzung der Flechten an jedem Fundort herangezogen und die Standorte mittels des Non-metric Multidimensional Scaling (NMS) als Ordinationsmethode und Clusteranalysen basierend auf

„Sørensen's coefficient of dissimilarity" als Klassifikationmethode ordiniert und zu klassifiziert.

- Die größte Unähnlichkeit wurde innerhalb der Standorte im Atlantischen Regenwald gefunden, mit einem Durchschnittswert von 21% und einem Maximum von 55%. Die Artenzusammensetzung der Flechten von allen Fundorten im Atlantischen Regenwald insgesamt verglichen mit den Fundorten der Caatinga zeigte eine maximale Unähnlichkeit mit Werten zwischen 0.92 oder 8% gemeinsamer Arten. Ähnliche Unähnlichkeitswerte wurden beim Vergleich von Caatinga and Brejos de Altitude Standorten gefunden.

- Der Einfluss der Rindenbeschaffenheit und der Phorophytenarten (Trägerarten) auf Artenzusammensetzung, Artenreichtum und Flächendeckung der Flechten in einem ausgewählten Teilstück des Atlantischen Regenwaldes wird analysiert, um zu ermitteln, wie sich die Diversität der Bäume auf die Artenvielfalt rindenbewohnender Flechten und die räumliche Verteilung von Flechtenarten innerhalb des Waldes auswirkt.

- Die multivariate Analyse der Fundorte, einschließlich Non-metric Multidimensional Scaling (NMS), Detrended Correspondence Analysis (DCA) und Canonical Correspondence Analysis (CCA) sowie Clusteranalysen weisen sowohl auf subtile Muster bezüglich der Präferenzen für Phorophyten (Trägerpflanzen) bestimmter Flechtenarten hin, als auch auf eine Korrelation mit Umweltparametern, insbesondere pH-Wert der Rinde, Abschälungsgrad der Rinde und Dichte und Größe der Rindenlenticellen.

- Auch Individuelle und Multiple Korrelation zeigten Zusammenhänge zwischen Artenreichtum der Flechten und Flächendeckung einerseits sowie pH-Wert der Rinde (negativ), Dichte und Größe der Rindenlenticellen (negativ), Abschälungsgrad der Rinde (negativ), Vorhandensein von Milchsaft (positiv) und einem diffusen Standortfaktor (positiv) andererseits.

- Es wurden keine ausgeprägten Flechtegesellschaften an den beprobten Standorten entdeckt, doch lassen sich durch Clusteranalysen drei Hauptgruppen und sechs Untergruppen mit leicht unterschiedlicher Artenzusammensetzung der Flechten unterscheiden, jede mit charakteristischen Indikatorarten aber stark variabler allgemeiner Artenzusammensetzung.

- Es wird gefolgert, dass die Ausbildung von Flechtengesellschaften im Unterwuchs des tropischen Regenwaldes von zwei Hauptfaktoren gesteuert wird, den Rindeneigenschaften des Phorophyten und dem Mikroklima, doch wird dieser Zusammenhang weitgehend von den stochastischen Effekten von Artenverteilung und seltenen Arten und auch dem Ausmaß der Diversität der Trägerbäume überdeckt.

- Es wird vorhergesagt, dass die Phorophyten-Spezifität am besten in Modellsystemen mit geringer Baum- und Flechtenartendiversität, ausgeprägten Unterschieden zwischen den Baumarten hinsichtlich der Rindeneigenschaften, homogener Populationsstruktur und geringer Variabilität des Mikroklimas zu beobachten ist.

- Schließlich wurden bei der vorliegenden Studie drei verschiedene Erhebungsmethoden und ihre Effizienz hinsichtlich der bestmöglichen Abschätzung der Diversität tropischer Mikroflechten getestet: (I) einmalige nicht-quantitative opportunistische Probennahme pro Fundort (‚opportunistisch'), durchgeführt an 21 Fundorten, (II) dreimalige repetitive nicht-quantitative opportunistische Probennahme an einem einzigen Fundort (‚repetitiv') und (III) quantitative Probennahme entlang eines Transekts an einem einzigen Fundort (‚quantitativ').

- Die Analyse zeigte, dass mit einer opportunistischen Erhebung nicht die seltenen, unauffälligen, sterilen und/oder kryptischen Arten erfasst werden, die im Gelände gewöhnlich vernachlässigt oder übersehen werden. Dementsprechend waren von den 456 an den 22 untersuchten Standdorten gesammelten und identifizierten Flechtenarten nicht weniger als 76 Arten auf das quantitativ beprobte Transekt beschränkt, und unter den mit dieser Methode erhobenen Flechtenarten befand sich

ein signifikant höherer Anteil an seltenen, unauffälligen, sterilen und/oder kryptischen Arten.

- Es wird auch ersichtlich, dass nicht die höhere Anzahl von Einzelproben, die durch quantitative Erhebung erfasst wird, in einer höheren Artenzahl resultiert, sondern die Methode der Auswahl der Einzelproben, welche bei der opportunistischen Probennahme subjektiv ist und zugunsten häufiger, auffälliger, fertiler und/oder unverkennbarer Arten ausfällt, bei der quantitativen Erhebung jedoch objektiv und ohne bestimmte Tendenzen geschieht.

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4. Declaration of the self-contribution to research articles resulting from the completion of the present work

Cáceres MES (2007). **New and otherwise interesting taxa of corticolous microlichens from northeastern Brazil**

Contribution to the completion of the work: ~ 90%

I conducted the field work, collected all the lichen samples during the various field trips to Brazil. I identified 75% of the lichen material and actively collaborated in the identification of the remaining specimens with other specialists (A. Aptroot, K. Kalb, R. Lücking, H. Sipman). I created the specimen and taxonomic database from which the body of the manuscript was extracted. I wrote 80% of the manuscript, and received partial assistance from Dr. Robert Lücking in the description of the new species and the taxonomic discussion of some of the taxa, and from Dr. Gerhard Rambold in the general structure of the manuscript. The manuscript was critically revised by Prof. Dr. Rambold and Dr. Lücking.

Cáceres MES, Lücking R, Rambold G (2007). **The corticolous microlichen biota in three principal vegetation types of northeastern Brazil: coastal Mata Atlântica, Caatinga, and Brejos de Altitude**

Contribution to the completion of the work: ~ 75%

I conducted the field work, identified 75% of the lichen material (see above), and wrote 75% of the manuscript. Dr. Gerhard Rambold contributed with the discussion of the results and gave me assistance on the presentation of the data. Dr. Robert Lücking assisted with the statistical analyses.

Cáceres MES, Lücking R, Rambold G (2007). **Phorophyte specificity and environmental parameters as determinants for species composition, richness and area cover in corticolous crustose lichen communities in the Atlantic rainforest of northeastern Brazil**

Contribution to the completion of the work: ~ 75%

I conducted the field work and did all the data analysis including mapping and quantitative elaboration of samples, and I am responsible for 80% of the identification of the lichen material. The statistical analyses were done in collaboration with Dr. Robert Lücking. The manuscript was written by me (70%) together with the other co-aouthors (30%).

Cáceres MES, Lücking R, Rambold G (2007). **Efficiency of sampling methods for accurate estimation of species richness: corticolous microlichens in the Atlantic rainforest of Northeastern Brazil**

Contribution to the completion of the work: ~ 75 %

I conducted the field work, identified the lichen species and wrote 70% of the manuscript. The "results" and "discussion" were written in collaboration with the other co-aouthors of the work.

Bayreuth, den 1.12.2006

Marcela Silva Cáceres

(Marcela Eugênia da Silva Cáceres)

4. Erklärung

Hiermit versichere ich, die vorliegende Arbeit selbständig verfasst und keine anderen als die von mir angegebenen Quellen und Hilfsmittel verwendet zu haben.

Ferner versichere ich, dass ich anderweitig mit oder ohne Erfolg nicht versucht habe, diese Dissertation einzureichen. Diese oder eine gleichartige Doktorprüfung wurde von mir an keiner anderen Hochschule endgültig nicht bestanden.

Bayreuth, den 1.12.2006

(Marcela Eugênia da Silva Cáceres)

CÁCERES, M. E. S. (2007): **Corticolous crustose and microfoliose lichens of northeastern Brazil.**

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Corticolous crustose and microfoliose lichens of northeastern Brazil

Marcela Eugenia da Silva Cáceres

2007

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Abstract

A total of 456 species of corticolous crustose and microfoliose lichens are reported from the states of Rio Grande do Norte, Paraiba, Pernambuco, Alagoas and Sergipe in northeastern Brazil, based on more than 2,700 collections made at 22 localities representing the three major vegetation types, coastal Atlantic rainforest or Zona da Mata (Mata Atlântica), Brejos de Altitude, and Caatinga, as well as the transitional Agreste region. Of the 456 species, 426 were identified: 370 could be identified to genus and species level, while further 35 were tentatively identified to species level and 21 species could not be named to species level due to lack of critical revisions of the corresponding genera. A further 30, sterile species were recognized as distinct taxa due to morphological, anatomical, and chemical features, but could not be named to genus and species level due to lack of critical characters; these taxa are not treated here in detail. A partially annotated, alphabetical list of the identified taxa is presented, accompanied by keys to genera and species as well as specimen citations, and a systematic classification for all taxa is presented. More than half of the species, 255 taxa, are illustrated with habit photographs, to facilitate their identification in addition to the anatomical and chemical features outlined in the keys. The following 18 species are described as new: *Aciculopsora cinerea* Cáceres & Lücking spec. nova, *Bacidina digitalis* Cáceres & Lücking spec. nova, *B. multiseptata* Cáceres & Lücking spec nova, *Calopadia bonitensis* Cáceres & Lücking spec. nova, *Cryptothecia subcandida* Cáceres & Lücking spec. nova, *Diorygma alagoense* Cáceres & Lücking spec. nova, *Echinoplaca caruaruensis* Cáceres & Lücking spec. nova, *Enterographa chiodectonoides* Cáceres & Lücking spec. nova, *E. subquassiaecola* Cáceres & Lücking spec. nova, *Graphis pernambucoradians* Cáceres & Lücking spec. nova, *G. pilarensis* Cáceres & Lücking spec. nova, *G. stellata* Cáceres & Lücking spec. nova, *Malcolmiella atlantica* Cáceres & Lücking spec. nova, *M. badimioides* Cáceres & Lücking spec. nova, *M. flavopustulosa* Cáceres & Lücking spec. nova, *Phaeographis rubrostroma* Cáceres & Lücking spec. nova, *Plectocarpon syncesioides* Cáceres & Lücking spec. nova, and *Sarcographa fissurinoides* Cáceres & Lücking spec. nova. In addition, the following 14 new combinations are proposed: *Arthonia andamanica* (Makhija & Patw.) Cáceres & Lücking comb. nova, *Bacidia fluminensis* (Malme) Cáceres & Lücking comb. et stat. nova, *Chapsa leprocarpoides* (Hale) Cáceres & Lücking comb. nova, *C. punicea* (Müll. Arg.) Cáceres & Lücking comb. nova, *C. sublilacina* (Ellis & Everh.) Cáceres & Lücking comb. nova, *C. velata* (Müll. Arg.) Cáceres & Lücking comb. nova, *Graphis parallela* (Müll. Arg.) Cáceres & Lücking comb. nova, *Malcolmiella furfurosa* (Tuck. ex Nyl.) Cáceres & Lücking comb. nova, *M. fuscella* (Müll. Arg.) Cáceres & Lücking comb. nova, *M. gyalectoides* (Vain.) Cáceres & Lücking comb. nova, *M. hypomela* (Nyl.) Cáceres & Lücking comb. nova, *M. leptoloma*

(Müll. Arg.) Cáceres & Lücking comb. nova, *M. perisidiata* (Malme) Cáceres & Lücking comb. et stat. nova, and *M. polycampia* (Tuck.) Cáceres & Lücking comb. nova. Most of the listed species are new records for the study area; several are new to Brazil, and some are new to the Neotropics. The total number of lichens known from the study area, including previously reported macrolichen and foliicolous lichens is not estimated to be more than 700.

Key words: Alagoas, crustose lichen biodiversity, new species, Paraiba, Pernambuco, Rio Grande do Norte, Sergipe

Introduction

Tropical rainforests have fascinated naturalists and casual travelers ever since the first contact with this exotic vegetation by Europeans centuries ago. In fact, the term tropical rainforest ('tropischer Regenwald') was first used by the German botanist A. F. W. Schimper in 1898, to describe the forests of the permanently wet tropics (WHITMORE 1990). The most impressive characteristic of this exuberant vegetation, so different from what is found in northern Europe and North America, is the enormous species richness, with the largest numbers of co-existing plant and animal species so far reported.

Only recently, it has been established that the tropics also house ecosystems with the greatest lichen diversity in the world (GALLOWAY 1991, 1992; GRADSTEIN 1992; LÜCKING 1995; APTROOT 1997a, b; APTROOT & SIPMAN 1997; KOMPOSCH & HAFELLNER 1999, 2000, 2002; LÜCKING & MATZER 2001; COPPINS & WOLSELEY 2002; SIPMAN & APTROOT 2001; LÜCKING *et al.* 2004). It was always a common belief that extratropical regions had the greatest global lichen diversity, which was supported by so many years of lichenological research and collections in Europe and North America (POELT 1969; CLAUZADE & ROUX 1985; PURVIS *et al.* 1992; SANTESSON 1993; WIRTH 1995; BRODO *et al.* 2001). Yet, with the increasing amount of studies and field trips to tropical regions, more and more species have been reported and also described from tropical Asia and Australia (APTROOT 1997a, b; APTROOT *et al.* 1997; APTROOT & SEAWARD 1999; APTROOT & SIPMAN 2001; LÜCKING *et al.* 2001), Africa (SWINSCOW & KROG 1988; LÜCKING & KALB 2002; FRISCH *et al.* 2006), and Central and South America (KAPELLE & SIPMAN 1992; LÜCKING 1992, 1995; KOMPOSCH & HAFELLNER 1999, 2000; BÜDEL *et al.* 2000; BREUSS 2000, 2001, 2004; CHAVES *et al.* 2004; LÜCKING *et al.* 2006; NELSEN *et al.* 2006; RIVAS PLATA *et al.* 2006). Also, more and more revisions and monographs are becoming available for tropical lichens (HALE 1974, 1975, 1976a, 1976b,

1978, 1981; KALB 1987; KALB & VEZDA 1988 a, b; MOBERG 1990; BRAKO 1991; STAIGER & KALB 1995; TEHLER 1997; AHTI 2000; MARBACH 2000; STAIGER 2002; KALB *et al.* 2000, 2004; FRISCH *et al.* 2006).

The checklist of lichens from Brazil, published by Marcelo Marcelli on the lichen checklist website (MARCELLI 2005), contains about 3,000 records, the largest number of any country in the world. Foliicolous lichens alone amount to more than 300 species (LÜCKING & KALB 2000). Yet, for several reasons, our knowledge of the Brazilian lichen flora, presumably one of the richest in the world, is still rudimentary for many areas and taxonomic groups. First, there is a clear geographical and taxonomic bias with regard to published floras towards central and southern Brazil and towards macrolichens (chiefly Parmeliaceae) and foliicolous lichens. Few reliable data exist for the diversity of crustose microlichens and for Amazonian and northeastern Brazil. Secondly, few modern revisions exist for many groups, for which names have been published and included in the checklist. This is particular true of crustose microlichens on rock and bark surfaces, which in a country like Brazil, with vast areas of dry vegetation and continental lowland rainforest, will account for at least 50 % of its lichen diversity. Although these lichens have been extensively sampled by various workers, the few modern accounts available do not correspond to the diversity to be expected. Based on this, the objective of the present study was to document the diversity of corticolous crustose and microfoliose lichens in northeastern Brazil, since these are supposed to contribute most to tropical lichen species richness and since northeastern Brazil is the least studied region in the country with respect to its corticolous crustose and microfoliose lichen biota. In addition, the ecology of corticolous crustose and microfoliose lichens in northeastern Brazil is treated in three separate papers (CÁCERES *et al.* 2007a–c).

Lichenology in Brazil

Brazil has an outstanding tradition concerning lichenology in tropical America. In the 19th and early 20th century, it was visited by important collectors and lichenologists, such as Gustav Malme and Edward August Vainio, the latter considered now the 'father of Brazilian lichenology' (MARCELLI 1998). Lichen collections from Brazil were treated in important floristic and monographic works, including those of Müller Argoviensis, Vainio, Malme, Redinger, and Santesson. The second half of the twentieth century initiated the modern systematic research on lichenized fungi, with many publications treating or citing Brazilian material. Among those, one may especially mention the works of Hale on Parmeliaceae (HALE 1975, 1976a, b). The most significant recent collections by a foreign researcher are those made by the

German lichenologist Klaus Kalb, which together with Vainio's and Malme's collections are now the primary reference for anyone studying lichens in Brazil and the Neotropics in general (KALB 1981, 1987, 2001, 2004; KALB & VĚZDA 1987; BRAKO 1991; KASHIWADANI & KALB 1993; KALB & ELIX 1995; STAIGER & KALB 1995, 1999; LÜCKING & KALB 2000; MARBACH 2000; STAIGER 2002; KALB *et al.* 2000, 2004; FRISCH *et al.* 2006).

In more recent times, many foreign lichenologists, including Klaus Kalb, André Aptroot, Lois Brako, Lidia Ferraro, Hector Osorio, Teuvo Ahti, Robert Lücking, and the author of this paper, continued gathering lichens in Brazil, and lichenological working groups established in Recife, São Paulo, and Rio Grande do Sul (MARCELLI 1998; CÁCERES *et al*. 2000). Beginning in the early 1970s, the Uruguayan lichenologist Héctor Saúl Osorio initiated a detailed inventory of the lichen biota of southern Brazil (e.g. OSORIO 1973, 1981, 1992, 1998), later continued by his collaborator and Brazilian lichenologist Mariana Fleig and her student Sionara Eliasaro in Rio Grande do Sul and Paraná (e.g. OSORIO & FLEIG 1982, 1994; FLEIG 1985, 1990, 1995, 1999; FLEIG *et al.* 1995; ELIASARO & ADLER 1997, 2000; ELIASARO & DONHA 2003; FLEIG & GRÜNINGER 2000), by Klaus Kalb's collaborator Marcelo Marcelli and his students in São Paulo and central Brazil (PEREIRA & MARCELLI 1989; MARCELLI 1991, 1992, 1993, 1995; AHTI & MARCELLI 1995; MARCELLI & RIBEIRO 2002), and by the Argentinian lichenologist Lidia Itati Ferraro in southern Brazil (FERRARO & ELIX 1993; FERRARO & LÜCKING 2000). Several groups specialising on lichen chemistry and its applications emerged in the states of Paraná, Mato Grosso do Sul, and São Paulo (GORIN *et al.* 1988, 1993; HONDA *et al.* 1995; SAIKI *et al.* 1997; HONDA & VILEGAS 1998; MARCELLI 1998).

These publications document the output of floristic and taxonomic contributions on lichens mainly from northeastern, central and southern Brazil by local researchers, balancing the many studies by foreign workers which usually extracted most or all of the material from the country. Thus, the main collections now available in Brazil are those gathered by Batista, Xavier Filho, Pereira, Fleig and Marcelli and their students (MARCELLI & RIBEIRO 2002; BENATTI 2005; CANÊZ 2005; KÄFFER 2005; SPIELMANN 2005; JUNGBLUTH 2006), housed at the Instituto de Botânica in São Paulo, and the Federal University of Pernambuco in Recife (URM). Marcelli is also the founder of the Checklist of Lichens from Brazil, available online at http://www.biologie.uni-hamburg.de/checklists/southamerica/brazil_l.htm, which currently lists some 3,000 species. This number probably underestimates the diversity expected from this vast country; it includes many old names that have to be revised, while many more species remain to be discovered.

Lichenology in Northeastern Brazil

The first significant contributions to lichenology by a Brazilian researcher were undoubtedly made by the mycologist Augusto Chaves Batista [*1916-1967*] and his students from Pernambuco state in northeastern Brazil (CARNEIRO 1968; DA SILVA & MINTER 1995; LÜCKING *et al.* 1998b, 1999). The work of Batista's group impacted mycology and lichenology far beyond the borders of Brazil, not only because of the immense number of new taxa described, but also because Batista and his students consequently applied dual nomenclature also to lichenized fungi, describing many new names for anamorphs of chiefly foliicolous lichens (LÜCKING *et al.* 1998). In terms of general mycology, the many fungal and lichen names published by Batista and his group have been considered a major breakthrough to the knowledge of the fungal and lichen biota of Brazil (DA SILVA & MINTER 1995). However, the fate of the lichen names published by this group (LÜCKING *et al.* 1998, 1999), together with the fact that most of these names refer to foliicolous or soil taxa, and considering the unfortunate situation that many of these collections are not well-preserved, indicates that Batista's work, inspite of its huge impact on mycology and lichenology, only represents a minor part of the fungal and lichen diversity to be expected from Brazil.

Batista initiated what was called the 'northeastern tradition' (PEREIRA 1996, 1998; MARCELLI 1998), continued until the present by his student Lauro Xavier Filho and Xavier Filho's student Eugênia Cristina Pereira. Both Xavier Filho and Pereira focused their studies on lichen chemistry and the diverse applications of secondary lichen substances, including the production of lichen metabolites from cell cultures and cell immobilization (PEREIRA *et al.* 1995a, b, 1999, 2002; PEREIRA 1998; FONTANIELLA *et al.* 2000; BLANCO *et al.* 2002; FALCÃO *et al.* 2002; DE CARVALHO *et al.* 2005). Yet, until now no comprehensive lichen inventory has been undertaken in northeastern Brazil north of Bahia state, including the northern part of the Atlantic rainforest and adjacent Caatinga vegetation, although the major vegetation types of this area (Zona da Mata, Caatinga, Brejos de Altitudes) are supposed to have a high lichen diversity. The first to report lichens from Pernambuco was MÜLLER ARGOVIENSIS (1891). A few macrolichens were published by XAVIER FILHO & MARIZ (1970), XAVIER FILHO & KUROKAWA (1971), BEZERRA *et al.* (1973), and XAVIER FILHO (1979). Species of Cladoniaceae were treated by AHTI *et al.* (1993) and AHTI (2000), and occasional microlichens were cited in other monographic treatments (HARRIS 1986; SPARRIUS 2004). BARROS & XAVIER-FILHO (1972) published a catalogue of lichens housed in the herbarium of the Federal University of Pernambuco in Recife (URM), but as a matter of fact, most of the lichen samples cited in this compilation are from areas outside Brazil, including Europe, which came to the herbarium by exchange. On the other hand, the mycologist

Augusto Chaves Batista and his collaborators made extensive collections of foliicolous lichens in the area (SILVA & MINTER 1995), and although most of their identifications had to be subsequently corrected (LÜCKING *et al.* 1998, 1999a, b), the number of foliicolous lichen species for the area surpasses 200 (CÁCERES *et al*. 2000).

The author of the present work started her interest in the lichen biota of Brazil working with foliicolous lichens which grow on the living leaves on vascular plants. After STIRTON's (1879) classic paper, these lichens were first monographed by SANTESSON (1952), who mentioned more than 150 species for Brazil. Foliicolous lichens from Brazil, including several new species, were also reported by Ferraro and collaborators (FERRARO 1997; LÜCKING & FERRARO 1997; FERRARO & LÜCKING 1997, 1999, 2000, 2003; FERRARO *et al.* 2001), and a small ecological paper was presented by LOMBARDI *et al.* (1999). Based on her M.Sc. thesis, the author and her collaborators described several new species of foliicolous lichens from Brazil (CÁCERES 1999; LÜCKING & CÁCERES 1999; CÁCERES & LÜCKING 2000) and presented an ecological and biogeographical study on the group in the Atlantic rainforest in Northeastern Brazil (CÁCERES *et al.* 2000). In this work, it was shown that the fragmented Atlantic rainforest remnants only conserve a small part of the overall foliicolous lichen diversity and that conservation of larger areas and corridors is needed to maintain high levels of species diversity in this threatened ecosystem. Also, it could be shown that selected logging not only reduces foliicolous lichen diversity but also alters community structure and particularly threatens those communities adapted to light gaps in the forest understory. The present work is thus a logical extension of these earlier studies, moving forward towards the highly diverse corticolous crustose and microfoliose lichen biota of northeastern Brazil. Because of its relatively dry climate, with an average 1200–1500 mm maximum of annual precipitation in the Atlantic rainforest and no more than 500 mm in the Caatinga, and its scarcity of montane forests, the lichen biota of the Brazilian northeast is expected to consist mainly of crustose lichens, besides microfoliose taxa such as Physciaceae, certain Parmeliaceae, and Coccocarpiaceae. In spite of the harsh conditions, the total lichen diversity is expected to be rather high, probably somewhere between 800–1,000 taxa. The total number of species reported from the area before the present study was less than 300, about 200 of which are foliicolous species, which means that about 60–70% of the total diversity remain unexplored.

Study Area

With a total surface area of ca. 8,511,965 km^2 (land), Brazil is the fifth largest country in the world and the largest in South America, occupying about

half of the continent. Most part of the country (about 80%) is located in eastern South America, bordering the Atlantic Ocean, between the equator and the Tropic of Capricorn. Brazil shares common boundaries with every South American country except Chile and Ecuador. The national territory is politically subdivided in 26 states and a Federal District, which are grouped in five geographical regions: the northern, the northeastern, the southeastern, the southern, and the central region (Fig. 1).

Brazil also covers two of the three major rainforest blocks in the Neotropics, the Amazon rainforest and the Atlantic rainforest (WHITMORE 1990), which makes Brazil the country with the largest area of tropical rainforest on the globe. The Atlantic rainforest is one of the most endangered biomes in the world. It is considered one of the five most importent biodiversity 'hotspots' worldwide (MYERS *et al.* 2000), being one of the biologically richest yet most threatened regions. The Mata Atlântica features an exceptional number of endemic plants (2.7 % of world's total) and vertebrates (2.1 % of world's total) and more than 90% of its natural territory has been lost to deforestation. Eight out of the ten largest cities in Brazil were founded in original Mata Atlântica areas along the coast, where nowadays 70% of the country's population live. Due to urbanization and agriculture, only about 5–8 % of the original vegetation remain partially undisturbed (FIDEM 1987; WHITMORE 1990). In northeastern Brazil, the forest devastation is even more accentuated, where only 2% of this extremely rich biome is still undisturbed, and it occurs mostly in isolated scattered throughout a landscape dominated by agricultural uses. One of the consequences of the deforestation is the increasing drought, causing an even more prolonged dry season, which subsequently affects the already reduced and overstressed rainforest remnants.

The northeastern Region of Brazil is composed by the states of Maranhão, Piauí, Ceará, Rio Grande do Norte, Paraíba, Pernambuco, Alagoas, Sergipe and Bahia. Of these, the five coastal states Rio Grande do Norte, Paraíba, Pernambuco, Alagoas, and Sergipe, were selected as core area for the present study. This area comprises three main vegetation types: (1) the aforementioned Atlantic coastal rainforest (Zona da Mata), (2) the Caatinga, and (3) the Brejos de Altitude (ANDRADE-LIMA 1961, 1964; RIZZINI 1977; WHITMORE 1990; MARCELLI 1998; SILVA FILHO *et al.* 1998). The Atlantic rainforest, or Mata Atlântica, is here represented mostly by a narrow tropical forest strip along the coast, extending from Rio Grande do Norte to Sergipe and Bahia states (WHITMORE 1990). It is characterized as a perennial forest with pronounced dry season, including lowland coastal forests with areas of restinga (sand-bank formations) and mangroves. Some patches of Mata Atlântica are found as so-called Brejos de Altitude, high altitude tropical vegetation isolated from the coast and nested within drier Caatinga or transitional vegetation (ANDRADE-LIMA 1961, 1964; RIZZINI 1977). To distinguish these isola-

ted rainforest remnants, the coastal, continuous part of the Atlantic rainforest is called Zona da Mata.

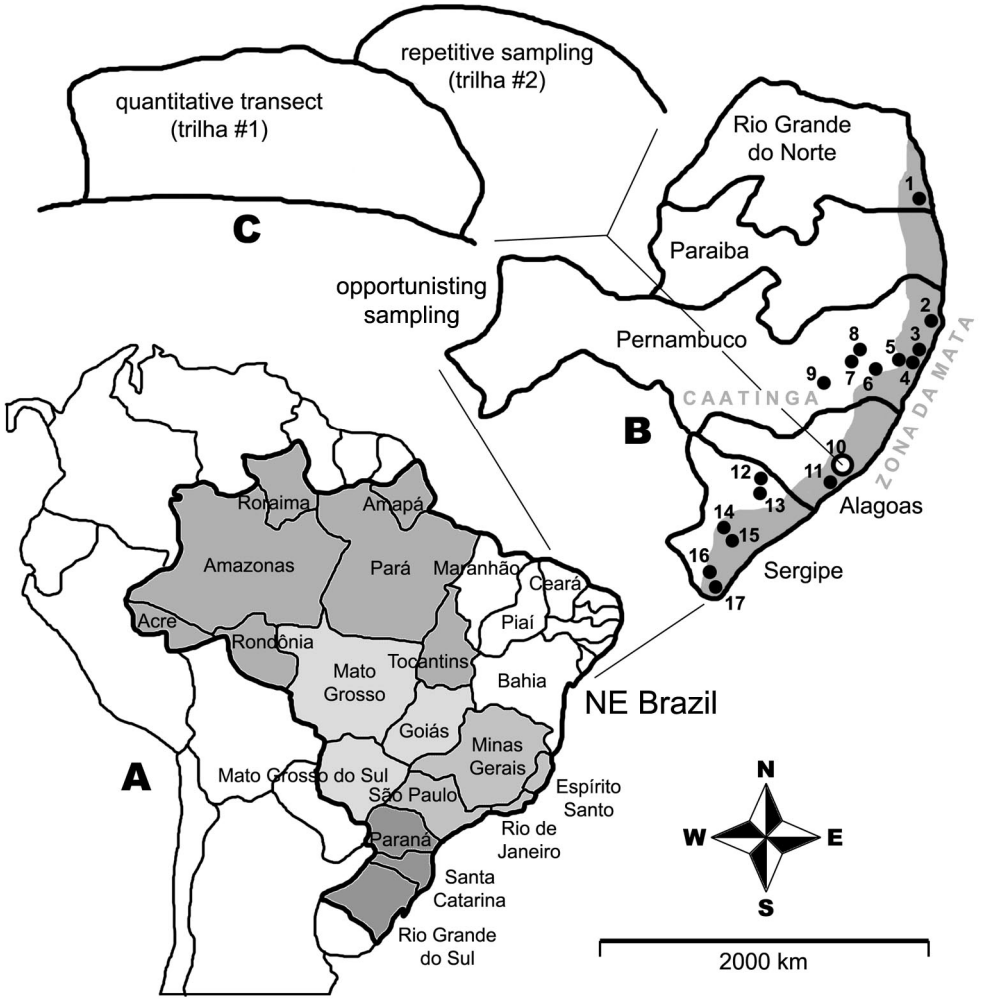

FIG. 1: Map of Brazil showing the five major geographic regions and the location of the study area and sites.

The trees in the Atlantic rainforest of northeastern Brazil can reach up to 40 m height, most of them reaching at least 15-25 m (ANDRADE-LIMA 1964; RIZZINI 1977). Typical trees from this part of the Mata Atlântica include, among others: *Tapirira guianenesis* Aubl. (Anacardiaceae), *Aspidosperma discolor* A. DC. (Apocynacea), *Copaifera nitida* Mart. ex. Hayne and *Sclerobium densi-*

florum Benth. (Caesalpiniaceae), *Clusia nemorosa* G.F.W. Mey., *Symphonia globulifera* Linn. (Clusiaceae), *Andira nitida* Mart. (Fabaceae), *Saccoglotis guianensis* Benth. (Humiriaceae), *Helicostylis tomentosa* Rusby, *Clarisia racemosa* Ruiz & Pav. (Moraceae), *Cupania vernalis* Cambess. (Sapindaceae), and *Apeiba albiflora* Ducke (Tiliaceae).

The field work was carried out during three field trips to northeastern Brazil from October to November 2000, April to May 2001 and September to October 2002. The general collections were made at 22 localities (Fig. 1), distributed along the Atlantic coast, within a range of about 700 km from north to south, covering the states of Rio Grande do Norte, Pernambuco, Alagoas, and Sergipe. The collecting sites were chosen with the purpose of covering as many forest remnants and vegetation types as possible distributed along the whole extension of the northern Atlantic rainforest and adjacent Caatinga vegetation. Since deforestation has already devastated most of the original vegetation cover, the rainforest remnants in this region are often located about 100–150 km apart from each other, some of them inside private properties. Two different Brejos de Altitude, elevated patches of isolated Mata Atlântica remnants within the dry Caatinga, were also included in the study area, as well as one locality of the transitional Agreste vegetation. The Caatinga vegetation was sampled at five localities in the states of Pernambuco and Sergipe. The complete location of the localities and date of collections are listed below:

1. Rio Grande do Norte, municipality of Baía Formosa, RPPN Mata Estrela Senador Antônio Farias, 75 km S of Natal and 50 km N of Mamanguape, on highway BR 101; 06º 22' S, 35º 01' W, sea level; remnant of Atlantic rainforest; April 2001.
2. Pernambuco, municipality of Igarassu, Refúgio Ecológico Charles Darwin, 30 km N of Recife and 5 km S of Itapissuma, on the highway BR101 to João Pessoa; 07º 50' S, 34º 54' W, 19 m; remnant of Atlantic rainforest (Zona da Mata); October 2000.
3. Pernambuco, municipality of Recife, Horto Zoobotânico de Dois Irmãos; 08º 05' S, 35º 03' W, 30 m; strongly disturbed remnant of Atlantic rainforest; 1998.
4. Pernambuco, municipality of Recife, Campus of the Universidade Federal de Pernambuco; 08º 06' S, 35º 03' W, 30 m; planted trees on campus, 1998.
5. Pernambuco, municipality of Cabo de Santo Agostinho, Estação Ecológica de Gurjaú (COMPESA), 24 km S of Recife; 08º 19' S, 35º 04' W, 30 m; remnant of Atlantic rainforest; October 2000.
6. Pernambuco, municipality of Cabo de Santo Agostinho, Estação Ecológica de Gurjaú (COMPESA), 24 km S of Recife; 08º 19' S, 35º 04' W, 30 m; exposed vegetation near remnant of Atlantic rainforest; October 2000.
7. Pernambuco, municipality of Cabo de Santo Agostinho, Barragem (COMPESA), 24 km S of Recife; 08º 19' S, 35º 04' W, 30 m; small, strongly disturbed remnant of Atlantic rainforest; October 2000.
8. Pernambuco, municipality of São Lourenço da Mata, Estação Ecológica de Tapacurá (Universidade Federal Rural de Pernambuco); 8º 02' S, 35º 09' W, 100–150 m; semideciduous remnant of Atlantic rainforest in transitional Agreste region towards Caatinga; 1998.

9. Pernambuco, municipality of Bonito, Parque Municipal de Bonito, 96 km SW of Recife and 25 km S of Bezerros; 08º 28' S, 35º 43' W, 800 m; isolated high altitude remnant of Atlantic rainforest (Brejo de Altitude); October 2000.
10. Pernambuco, municipality of Caruaru, Brejo dos Cavalos, 153 km W of Recife and 10 km S of Caruaru, near Murici; 08º 20' S, 35º 58' W, 800–900 m; ; isolated high altitude remnant of Atlantic rainforest (Brejo de Altitude); October 2000.
11. Pernambuco, municipality of Caruaru, Brejo dos Cavalos, 153 km W of Recife and 10 km S of Caruaru, near Murici; 08º 20' S, 35º 58' W, 800–900 m; exposed fence posts along road; October 2000.
12. Pernambuco, municipality of Caruaru, Estação Experimental do IPA (Instituto de Pesquisas Agropecuárias), 150 km W of Recife and 5 km NE of Caruaru, on road to Riacho das Almas; 08º 15' S, 35º 56' W, 500–600 m; dense Caatinga vegetation; October 2000.
13. Pernambuco, municipality of Caruaru, Estação Experimental do IPA (Instituto de Pesquisas Agropecuárias), 150 km W of Recife and 5 km NE of Caruaru, on the road to Riacho das Almas; 08º 15' S, 35º 56' W, 500–600 m; exposed secondary vegetation and planted trees; October 2000.
14. Pernambuco, municipality of Garanhuns, on the sides of the main road from BR 232 from Caruaru, 228 km SW of Recife, on the outskirts of the city, 08º 52' S, 36º 29' W, 800 m; exposed secondary vegetation; March 1998.
15. Alagoas, municipality of Pilar, RPPN Fazenda São Pedro, 24 km N of São Miguel dos Campos and 25 km NW of Praia do Francês, on the highway BR101; 09º 37' S, 35º 58' W, 50 m; remnant of Atlantic rainforest; April 2001, October 2001, September 2002.
16. Alagoas, municipality of Barra de São Miguel, RPPN Rosa do Sol, 24 km SE of São Miguel dos Campos and 50 km S of Maceió, on the highway BR101; 09º 51' S, 35º 53' W, 50 m above sea level; small remnant of Atlantic rainforest; on bark of undetermined tree, April 2001.
17. Sergipe, municipality of Gararu, on the right side of the road from Itabi to Gararu, about 5 km S of Gararu, 10 km SE of Porto da Folha and 100 km N of Aracaju; 09º 58' S, 37º 54' W, 0–100 m above sea level; Caatinga vegetation; October 2002.
18. Sergipe, municipality of Itabi, on the left side of the road from Itabi to Gararu, about 2 km N of Itabi, 10 km SE of Porto da Folha and 100 km N of Aracaju; 10º 06' S, 37º 54' W, 0–100 m above sea level; mixed Caatinga vegetation; October 2002.
19. Sergipe, municipality of Itabaiana, Povoado Ribeira, Fazenda São José, on the road BR 235 from Aracaju to Itabaiana, between Areia Branca e Itabaiana turn left following a smaller road to Ribeira, about 40 km NW of Aracaju and 15 km SE of Itabaiana; 10º 45' S, 37º 20' W, 500 m; remnant of Atlantic rainforest; September 2002.
20. Sergipe, municipality of Areia Branca, Reserva Ecológica da Serra de Itabaiana, on the road BR 235 from Aracaju to Itabaiana, 3 km after Areia Branca, on the right side, about 36 km NW of Aracaju and 20km SE of Itabaiana; 10º 45' S, 37º 20' W, 500 m; remnant of Atlantic rainforest; October 2002.
21. Sergipe State, municipality of Estância, near povoado Ribeira, on the road BR 235 from Aracaju to Itabaiana, 3 km after Areia Branca, on the left side, about 36 km NW of Aracaju and 20km SE of Itabaiana; 10º 40' S, 37º 21' W, 300 m; remnant of Atlantic rainforest; April 2001.
22. Sergipe State, municipality of Santa Luzia do Itanhy, on a small road on the left side of BR 101, about 10 km SE of Estância and 65 km S of Aracaju, bordering the grounds of the Fazenda de José Leite ; 11º 21' S, 37º 26' W, 100 m; remnant of Atlantic rainforest; October 2000.

Material and Methods

Three different sampling methods were employed: (I) one-time non-quantitative opportunistic sampling per site (all 22 localities), (II) three-times repetitive non-quantitative opportunistic sampling at a single site (RPPN Fazenda São Pedro), and (III) quantitative transect sampling at a single site (also RPPN Fazenda São Pedro). Opportunistic sampling followed the suggestions made by SIPMAN (1996), with phorophyte trees selected along the main trails within the rainforest fragments as well as penetrating the vegetation when possible. Phorophyte trees were approached both randomly and based on visual selection through the presence of conspicuous lichen thalli, and each tree was inspected for about 3–5 minutes. Specimens were collected of all lichen thalli recognized as different from each other in the field, usually 1–5 per tree. With this method, a number of 50–100 phorophyte trees per locality was analyzed and about 100–200(–300) lichen samples collected per locality.

For the quantitative sampling at RPPN Fazenda São Pedro (CÁCERES *et al.* 2007b, c), collections were made along a transect laid on one of the main trails. A total of 47 phorophytes belonging to 16 different tree species were selected. Sample rectangles of 60 × 20 cm^2 each were placed on the trunk of each phorophyte at breast height. All lichen thalli located inside each of the 47 sample rectangles were registered and identified to species level using morphological, anatomical and chemical characters.

For the identification of the lichen species, the samples were at first examined under a stereomicroscope with up to 50× magnification, in order to study the macroscopical characters, such as color and structure of the thallus, as well as ascomata and conidiomata if present. Thin hand sections of ascomata and other structures when necessary were made using a razor blade. The sections were placed on a microscope slide in water and covered with a cover slip and examined under a compund microscope with 10×, 40×, and 100× magnifications.

K (10% potassium hydroxide solution) and C (commercial bleach) were used under the stereomicroscope to observe color reactions of thallus and/or ascomata. I (commercial SIGMA Lugol's solution) was applied under the compound microscope to test for hymenial amyloidity and ascus wall structures. When necessary, chemical compounds were analyzed using thin layer chromatography (TLC) following standard methods by CULBERSON & KRISTINSSON (1970), CULBERSON & AMMAN (1979), and LUMBSCH (2002).

The identification key for tropical lichens by SIPMAN (2003) and the LIAS genera key, both available on the Internet, were followed for the identification of tropical crustose lichens at generic level. For the identification and nomenclature of more specific groups at species level, many individual

treatments were used which are cited under each genus. Specific literature was also consulted for the identification of genera in some major groups, such as STAIGER (2002) for Graphidaceae, MARBACH (2000) for Buellia s.l., and FRISCH *et al*. (2006) for Thelotremataceae. In addition to the cited literature and the specimens at hand, the LIAS glossary (RYAN et al. 2005-2006) and LIAS genera key (RAMBOLD & TRIEBEL 1995-2006), both available online, were also consulted for the construction of the key to genera and species.

Representative sets of specimens are deposited in the following herbaria: Instituto de Micologia, Universidade Federal de Pernambuco, Recife, Brasil (URM), including most of the type material of new species; Botanischer Garten and Botanisches Museum Berlin-Dahlem, Germany (B); Field Museum of Natural History, Chicago, USA (F). Additional collections are distributed in the herbaria of A. Aptroot (ABL) and K. Kalb (hb. Kalb).

Taxonomic diversity

The present work yielded a total of 456 species of corticolous crustose and microfoliose lichens. Of these, 383 could be identified to genus and species level, while another 24 were tentatively identified to species level; 18 taxa could not be named to species level due to lack of critical revisions of the corresponding genera (in particular sterile species of *Cryptothecia* and Thelotremataceae). A further 30, sterile species were recognized as distinct taxa due to morphological, anatomical, and chemical features, but could not be named to genus and species level due to lack of critical characters; these taxa are not treated here in detail. The identified species comprise a number of 115 genera, distributed in 32 families, 12 orders, and 5 classes of Ascomycota and Basidiomycota (Table 1).

TABLE 1: Systematic arrangement and number of species per genus, family, and order, of the 426 corticolous crustose and microfoliose lichens identified in the present study. The classification follows STAIGER (2002), PERSOH *et al*. (2004), GRUBE *et al*. (2004), LUMBSCH *et al*. (2004a, b), LÜCKING *et al*. (2004), FRISCH *et al*. (2006), JAMES *et al*. (2006), SPATAPHORA *et al.* (2006), and MIADLIKOSWKA *et al.* (2006).

Basidiomycota	
Agaricomycetes	1 species
Agaricomycetidae	1 species
Atheliales	1 species
Atheliaceae	1 species
Dictyonema	1 species
Ascomycota	
Incertae sedis	1 species
Mycocaliciales	1 species
Sphinctrinaceae	1 species

Sphinctrina	1 species
Arthoniomycetes	79 species
Arthoniomycetidae	79 species
Arthoniales	79 species
Arthoniaceae	39 species
Arthonia	14 species
Arthothelium	3 species
Coniocarpon	3 species
Cryptothecia	11 species
Helminthocarpon	1 species
Herpothallon	7 species
Chrysothrichaceae	1 species
Chrysotrix	3 species
Roccellaceae	37 species
Bactrospora	3 species
Chiodecton	1 species
Cresponea	4 species
Dichosporidium	2 species
Enterographa	6 species
Lecanactis	1 species
Lecanographa	1 species
Mazosia	2 species
Opegrapha	12 species
Plectocarpon	1 species
Sagenidiopsis	1 species
Sclerophyton	1 species
Syncesia	2 species
Dothideomycetes	37 species
Pleosporales	2 species
Arthopyreniaceae	2 species
Arthopyrenia	1 species
Mycomycrothelia	1 species
Incertae sedis	35 species
Monoblastiaceae	10 species
Anisomeridium	5 species
Caprettia	1 species
Megalotremis	1 species
Musaespora	3 species
Strigulaceae	4 species
Strigula	4 species
Trypetheliaceae	21 species
Arthitrypethelium	1 species
Astrothelium	5 species
Bathelium	2 species
Cryptothelium	1 species
Laurera	2 species
Lithothelium	1 species
Polymeridium	1 species
Pseudopyrenula	2 species
Trypethelium	6 species
Eurotiomycetes	24 species
Chaetothyriomycetidae	24 species
Pyrenulales	23 species

Pyrenulaceae	23 species
Anthracothecium	2 species
Celothelium	1 species
Pyrenula	19 species
Pyrgillus	1 species
Verrucariales	1 species
Verrucariaceae	1 species
Flakea	1 species
Lecanoromycetes	284 species
Candelariomycetidae	1 species
Candelariales	1 species
Candelariaceae	1 species
Candelaria	1 species
Lecanoromycetidae	104 species
Lecanorales	79 species
Brigantiaeaceae	1 species
Brigantiaea	1 species
Catillariaceae	2 species
Catillaria	2 species
Lecanoraceae	16 species
Haematomma	2 species
Lecanora	9 species
Maronina	1 species
Pyrrhospora	2 species
Traponora	1 species
Vainionora	1 species
Pilocarpaceae	37 species
Bapalmuia	3 species
Byssoloma	4 species
Calopadia	6 species
Eugeniella	2 species
Fellhanera	2 species
Lasioloma	1 species
Malcolmiella	18 species
Tapellaria	1 species
Ramalinaceae	22 species
Aciculopsora	1 species
Bacidia	4 species
Bacidina	6 species
Bacidiopsora	2 species
Crocynia	2 species
Phyllopsora	6 species
Squamacidia	1 species
Stereocaulaceae	1 species
Lepraria	1 species
Teloschistales	22 species
Letrouitiaceae	3 species
Letrouitia	3 species
Physciaceae	19 species
Baculifera	2 species
Cratiria	1 species
Dirinaria	6 species
Hafellia	4 species

Heterodermia	1 species
Physcia	2 species
Pyrine	1 species
Rinodina	1 species
Stigmatochroma	1 species
Peltigerales	2 species
Coccocarpiaceae	2 species
Coccocarpia	2 species
Incertae sedis	1 species
Lopezaria	1 species
Ostropomycetidae	179 species
Ostropales	171 species
Gomphillaceae	5 species
Aderkomyces	1 species
Echinoplaca	3 species
Tricharia	1 species
Graphidaceae	77 species
Anomomorpha	1 species
Carbacanthographis	3 species
Diorygma	6 species
Dyplolabia	2 species
Fissurina	6 species
Glyphis	3 species
Graphis	31 species
Hemithecium	2 species
Phaeographis	15 species
Platygramme	1 species
Platythecium	1 species
Sarcographa	5 species
Thalloloma	1 species
Coenogoniaceae	18 species
Coenogonium	18 species
Gyalectaceae	2 species
Cryptolechia	1 species
Ramonia	1 species
Myeloconidaceae	1 species
Myeloconis	1 species
Phlyctidaceae	1 species
Phlyctella	1 species
Porinaceae	21 species
Porina	19 species
Trichothelium	2 species
Stictidaceae	1 species
Stictis	1 species
Thelenellaceae	2 species
Aspidothelium	1 species
Thelenella	1 species
Thelotremataceae	43 species
Acanthotrema	1 species
Ampliotrema	2 species
Chapsa	13 species
Myriotrema	5 species
Ocellularia	13 species

Stegobolus	3 species
Thelotrema	5 species
Pertusariales	8 species
Pertusariaceae	8 species
Ochrolechia	1 species
Pertusaria	7 species

Key to genera

The following key for the identification of corticolous microlichens genera from northeastern Brazil refers to the taxa reported in this study. This key includes crustose and microfoliose lichen only. It also includes all genera of foliicolous lichens reported by CÁCERES *et al.* (2000), although the species are not treated in the annotated list. Genera with only one reported species have the epithet name given in parentheses.

1a. Thallus microfoliose, squamulose, or filamentous (sometimes appressed and then appearing crustose, but with distinct algal filaments visible under lens magnification) 2
1b. Thallus crustose 14

2a. Thallus (appressed) filamentous 3
2b. Thallus microfoliose or squamulose 4

3a. Photobiont green (*Trentepohlia*); fruit bodies ascomata ..... ***Coenogonium***
3b. Photobiont blue-green (*Scytonema*); fruit bodies basidiomata ..... ***Dictyonema* (*phyllogenum* f. *nitidum*)**

4a. Thallus microfoliose 5
4b. Thallus squamulose 9

5a. Thallus yellow, with calycin; ascospores colorless, non-septate, 20–50 per ascus ..... ***Candelaria* (*concolor*)**
5b. Thallus grey, with atranorin; ascospores brown, 1-septate, 8 per ascus. 6

6a. Rhizines and cilia absent; medulla UV+ blue-white, with divaricatic acid, or rarely medulla orange-red, K+ purple ..... ***Dirinaria***
6b. Rhizines and/or cilia present, usually abundant 7

7a. Upper cortex prosoplectenchymatous; lower cortex often absent; cilia usually present ..... ***Heterodermia* (*dissecta*)**

7b. Upper cortex paraplectenchymatous; lower cortex always present; cilia absent 8

8a. Apothecia lecideine when mature; lobe surface usually with reticulate maculae; medulla pigmented ..... ***Pyxine* (*berteriana*)**
8b. Apothecia lecanorine; lobe surface uniform or with indistinct maculae; medulla white..... ***Physcia***

9a. Thallus with large, rhizinate squamules loosely attached to the substrate; ascomata unknown ..... ***Flakea* (*papillata*)**
9b. Thallus with small, non-rhizinate squamules closely attached to substrate; ascomata apothecia..... 10

10a. Ascospores ellipsoid, non-septate, 6–18 μm long; hypothecium indistinctly delimited from basal and lateral parts of excipulum .... ***Phyllopsora***
10b. Ascospores fusiform to acicular, 18–60 μm long; hypothecium, basal and lateral excipulum well-delimited from each other..... 11

11a. Ascospores fusiform, less than 5 times as long as broad ....***Bacidia*** (spec.)
11b. Ascospores very narrowly fusiform to acicular, more than 10 times as long as broad..... 12

12a. Apothecia lecideine, with jet-black margin and dark brown excipulum; ascospores acicular, 1–2 μm broad .....***Aciculopsora* (*cinerea*)**
12b. Apothecia biatorine, with cream-colored to orange brown, rarely partically blackened margin and colorless to pale excipulum; ascospores very narrowly fusiform to cylindrical or bacillar, 2–4 μm broad..... 13

13a. Ascospores 0–3-septate, bacillar; with fumarprotocetraric or lobaric acid; large isidia usually present.....***Squamacidia* (*janeirensis*)**
13b. Ascospores 5–15-septate, very narrowly fusiform to cylindrical; with atranorin; isidia absent or small..... ***Bacidiopsora***

14a. Ascomata and ascospores present 15
14b. Ascomata and ascospores absent but conidiomata or soralia or isidia present (a few common corticolous taxa only)..... 152

15a. Ascomata apothecia, lirellae or mazaedia 16
15b. Ascomata perithecia (or resembling perithecia)..... 124

16a. Ascomata with mazaedium..... 17
16b. Ascomata without mazaedium; ascomata apothecia or lirellae..... 18

17a. Ascomata perithecioid, with narrow opening; ascospores 3-septate..... ..... ***Pyrgillus* (*javanicus*)**
17b. Ascomata apothecioid (resembling a burned cigarette tip), with wide opening; ascospores 1-septate ..... ***Tylophoron***

18a. Ascomata apothecia, rounded to angular..... 19
18b. Ascomata lirellae, distinctly elongate..... 97

19a. Apothecia compound, in distinct stromata or pseudostromata..... 20
19b. Apothecia solitary, rarely aggregated but not compound..... 26

20a. Ascospores large, non-septate; hymenium I+ blue..... ***Pertusaria***
20b. Ascospores small or narrow, transversely septate; hymenium I–, I+ orange-red or partially I+ blue..... 21

21a. Individual apothecia narrow, punctiform, resembling perithecia..... 23
21b. Individual apothecia broader, disciform..... 22

22a. Thallus byssoid..... ***Dichosporidium***
22b. Thallus compact..... 24

23a. Hypothecium of individual apothecia carbonized, black; ascospores often curved..... ***Chiodecton***
23b. Hypothecium of individual apothecia colorless to dark brown but not carbonized, low; ascospores fusiform, straight ..... ***Enterographa***

24a. Hymenium I+ orange-red, KI+ blue; ascospores with angular lumina, I–; paraphyses branched and anastomosing; thallus farinose, ecorticate, white to pale yellow ..... ***Syncesia***
24b. Hymenium I–; ascospores with lens-shaped lumina, I+ violet-blue or vine-red; paraphyses mostly unbranched except for marginal parts of hymenium; thallus smooth, corticate, green to brown 25

25a. Ascospores brown; hymenium inspers; thallus green ..... ***Sarcographa***
25b. Ascospores colorless; hymenium clear; thallus yellow-brown .... ***Glyphis* (*cicatricosa*)**

26a. Apothecia with thalline margin containing algae; margin of same color as thallus; proper margin usually reduced..... 27
26b. Apothecia with proper margin lacking algae, of different color as thallus and often of same color as disc, or margin absent..... 52

27a. Apothecial margin flush with disc, in section formed by a single tissue including algal cells (lecanorine); apothecia mostly sessile; hymenium and ascus tips I+ persistently blue; photobiont chlorococcoid 28
27b. Apothecial margin prominent over disc, in section formed by undifferentiated thalline layer with algae covering reduced proper excipulum; apothecia mostly immersed-erumpent, rarely sessile; hymenium often I–, rarely I+ orange-red, KI+ blue, or I+ blue (then ascus tips usually I–) 34

28a. Ascospores non-septate 29
28b. Ascospores transversely septate 33

29a. Ascospores more than 30 µm long, 1–8 per ascus 30
29b. Ascospores less than 20 µm long, 8 to many per ascus 31

30a. Ascospores thick-walled, more than 50 µm long; disc narrow ..... ***Pertusaria***
30b. Ascospores thin-walled, less than 50 µm long; disc wide ..... ***Ochrolechia* (*africana*)**

31a. Ascospores more than 8 per ascus; asci multispored ..... ***Maronina* (*multifera*)**
31b. Ascospores 8 per ascus 32

32a. Hypothecium dark brown ..... ***Vainionora* (*flavovirens*)**
32b. Hypothecium colorless ..... ***Lecanora***

33a. Apothecial disc red, K+ pink-purple; ascospores multiseptate, colorless ..... ***Haematomma***
33b. Apothecial disc brown, K–; ascospores 1-septate, brown ..... ***Rinodina***

34a. Hymenium I+ blue or I+ orange-red, KI+ blue 35
34b. Hymenium I– 38

35a. Hymenium I+ orange-red, KI+ blue; apothecial margin with distinct layers of brown excipular hyphae, colorless crystals and yellow-green algae ..... ***Mazosia***
35b. Hymenium I+ blue; apothecial margin different 36

36a. Ascospores filiform ..... ***Stictis* (*urceolata*)**
36b. Ascospores fusiform-ellipsoid 37

37a. Ascospores transversely septate; apothecia urceolate, with smooth margin ..... ***Ramonia* (*intermedia*)**

37b. Ascospores muriform; apothecia of *Chroodiscus*-type, with lobulate margin ..... ***Phlyctella* (*brasiliensis*)**

38a. Foliicolous; ascospores with thin septa and angular lumina 39
38b. Corticolous; ascospores mostly with thick septa and lens-shaped lumina 42

39a. Photobiont trentepohlioid (*Phycopeltis*); disc orange-red, K+ purple or grey, K+ yellow ..... ***Chroodiscus***
39b. Photobiont chlorococcoid (*Trebouxia*); disc variously colored but not as above 40

40a. Thallus with cortex of rectangular cells in radiate rows; paraphyses unbranched; ascospores often thick-walled with few septa; apothecia usually chroodiscoid, with lobulate margin, rarely urceolate; conidiomata pycnidia..... ***Asterothyrium***
40b. Thallus with cartilaginous or indistinctly cellular cortex; paraphyses richly branched and anastomosing; ascospores always thin-walled; apothecia usually urceolate, with smooth margin, rarely chroodiscoid; conidiomata hyphophores..... 41

41a. Hyphophores setiform, producing diahyphae at or below tips; ascospores mostly transversely septate, rarely muriform ..... ***Calenia***
41b. Hyphophores squamiform (but scales sometimes dissected into individual setae), producing diahyphae at their base; ascospores always muriform ..... ***Gyalectidium***

42a. Thallus UV+ yellow (lichexanthone); apothecia usually irregularly lobate, with pruinose disc and margin ..... ***Diorygma***
42b. Thallus UV–; apothecia rounded to angular but rarely lobate and then often with reticulate columella, margin usually epruinose..... 43

43a. Apothecia chroodiscoid, with widely open disc and erect to recurved, lobulate margin; periphysoids often present; excipulum colorless 44
43b. Apothecia discoid to urceolate, with narrow disc and entire margin; periphysoids usually absent; excipulum colorless or brown to carbonized 46

44a. Hymenium strongly inspersed; ascospores brown .....
..... ***Phaeographis* (*lobata*)**
44b. Hymenium clear; ascospores colorless, rarely brown 45

45a. Paraphyses with warty tips; isidia present.....
..... ***Acanthotrema* (*brasilianum*)**

45b. Paraphyses lacking warty tips; isidia absent ..... ***Chapsa***

46a. Apothecial margin not prominent; disc chocolate brown pruinose..... ..... ***Glyphis* (*scyphulifera*)**
46b. Apothecial margin prominent or disc immersed in thallus; disc not brown pruinose 47

47a. Apothecia of *Myriotrema*-type, immersed in thallus with small pores and indistinct margin; excipulum colorless 48
47b. Apothecia of *Ocellularia*-type, erumpent to prominent or sessile with large openings and distinct margin; excipulum brown to carbonized, rarely colorless..... 49

48a. Periphyses present; with stictic acid..... ***Thelotrema* (*glaucopallens*)**
48b. Periphyses absent; with psoromic acid or other substances ....***Myriotrema***

49a. Excipulum and ascospores colorless; periderm layer absent..... .....***Myriotrema***
49b. Excipulum brown to carbonized, if colorless then ascospores brown or columella distinctly reticulate; periderm layer present..... 50

50a. Hymenium inspersed; columella absent; with protocetraric acid..... .....***Ampliotrema***
50b. Hymenium clear; columella mostly present; with various substances... 51

51a. Columella distinctly reticulate; apothecia often irregular to lobate ....***Stegobolus***
51b. Columella more or less simple, narrow; apothecia rounded to angular .....***Ocellularia***

52a. Apothecial margin black, internally with dark brown pigment or carbonized but sometimes covered by pruina (lecideine) 53
52b. Apothecial margin pale or variously colored but not black, internally pale or pigmented but not dark brown to black (biatorine), or margin absent..... 63

53a. Hymenium I–; thallus with cortex of radiatately arranged, rectangular cells; foliicolous..... ***Psorotheciopsis***
53b. Hymenium I+ blue or I+ orange-red, KI+ blue; thallus ecorticate or with cortex of different structure; foliicolous or more often corticolous 54

54a. Ascospores brown, 1(–3)-septate 55
54b. Ascospores colorless, 3-septate to muriform..... 59

55a. Apothecial disc yellow pruinose ..... ***Stigmatochroma* (*gerontoides*)**
55b. Apothecial disc non-pruinose or weakly white-pruinose 56

56a. Hymenium inspers..... ***Hafellia***
56b. Hymenium clear 57

58a. Conidia bacillar, more than 6 µm long; epithecium K+ green.....
..... ***Baculifera***
58b. Conidia oblong-ellipsoid; less than 6 µm long; epithecium K–.....
..... ***Cratiria***

59a. Hymenium I+ blue; ascospores oblong to ellipsoid, thin-walled, transversely septate to muriform ..... ***Tapellaria***
59b. Hymenium I+ orange-red, KI+ blue; ascospores fusiform, slightly thick-walled, transversely septate..... 60

60a. Apothecial margin white to grey or pale yellow pruinose; thallus well-developed, pale green to white 61
60b. Apothecial margin black, non-pruinose; thallus thin, green to brown ...
..... 62

61a. Thallus finely byssoid with byssoid hypothallus; medulla dark brown; apothecia large, lobate ..... ***Sagenidiopsis* (*undulata*)**
61b. Thallus compact; medulla white; apothecia medium-sized, rounded to angular ..... ***Lecanactis* (*epileuca*)**

62a. Ascospores acicular-cylindrical, often with strong median constriction; disc black, non-pruinose..... ***Bactrospora***
62b. Ascospores fusiform; disc usually yellow pruinose ..... ***Cresponea***

63a. Apothecia not or hardly raised over thallus level, spot-like, emarginate or rarely with pale marginal zone, or asci scattered over thallus 64
63b. Apothecia distinctly prominent to sessile, usually with thin to distinct margin, very rarely emarginate..... 72

64a. Hymenium I–; photobiont chlorococcoid; thallus often verruculose due to clusters of calcium oxalate crystals 65
64b. Hymenium I+ blue or I+ orange-red, KI+ blue; photobiont trentepohlioid or chlorococcoid (then hymenium I+ blue); thallus smooth to farinose, lacking crystals 68

65a. Apothecia applanate, not raised over thallus level; hyphophores setiform or diahyphae adnate to thallus; diahyphae often strongly differentiated at tips 66
65b. Apothecia adnate, slightly raised over thallus level; hyphophores setiform but mostly with widened and flattened tip; diahyphae moniliform to filiform with little differentiation 67

66a. Diahyphae adnate to thallus; ascospores 1-septate; apothecia pale, translucent..... ***Actinoplaca***
66b. Hyphophores setiform with diahyphae produced (sub-)apically; ascospores 3-septate to muriform; apothecia yellow to dark brown .... ***Echinoplaca***

67a. Thallus with sterile setae, usually smooth..... ***Aderkomyces***
67b. Thallus lacking sterile setae, smooth to verruculose..... ***Gyalideopsis***

68a. Hymenium and ascus tips I+ blue; photobiont chlorococcoid; paraphyses unbranched, very thick, straight ..... ***Byssolecania***
68b. Hymenium I+ orange-red, KI+ blue, rarely I+ blue, but ascus tips I–; photobiont trentepohlioid; paraphyses branched and anastomosing, thin..... 69

69a. Ascomata white or asci scattered over thallus; hymenium lacking gelatinous matrix ..... ***Cryptothecia***
69b. Ascomata brown to black; hymenium with gelatinous matrix..... 70

70a. Conidia filiform, multiseptate; pycnidia oval..... ***Eremothecella***
70b. Conidia oblong to cylindrical, non-septate or 1(–3)-septate 71

71a. Apothecia applanate, hardly raised over thallus level; asci and paraphysoids in distinct hymenia ..... ***Arthonia***
71b. Apothecia prominent; asci formed in locules of pigmented stromatic tissue..... ***Arthothelium***

72a. Asci completely thin-walled; photobiont trentepohlioid; hymenium I+ blue rapidly turning sordid green then sordid brown 73
72b. Asci with apically thickened wall (at least when young or immature); photobiont chlorococcoid; hymenium I– or I+ persistently blue 74

73a. Ascospores 1-septate; apothecial margin not prominent. ***Coenogonium***
73b. Ascospores 3-septate; apothecial margin prominent..... ***Cryptolechia***

74a. Hymenium and ascus tips I– 75
74b. Hymenium and ascus tips I+ blue 77

75a. Thallus lacking sterile setae..... ***Gyalideopsis***
75b. Thallus with sterile setae 76

76a. Setae white; apothecia applanate to sessile; excipulum hyphal to prosoplectenchymatous..... ***Aderkomyces***
76b. Setae black; apothecia sessile to stipitate; excipulum prosoplectenchymatous to paraplectenchymatous..... ***Tricharia***

77a. Ascospores non-septate 78
77b. Ascospores septate to muriform 79

78a. Apothecial disc and margin bright red, K+ purple; asci of *Lecanora*-type ..... ***Pyrrhospora***
78b. Apothecial disc pale brown to brownish black, K–; asci of *Byssoloma*-type ..... ***Malcolmiella***

79a. Ascospores 1-septate 80
79b. Ascospores 3-septate to muriform..... 81

80a. Ascospores 2 per ascus, over 40 μm long ..... ***Lopezaria***
80b. Ascospores 8 per ascus, under 30 μm long ..... ***Catillaria***

81a. Ascospores transversely septate 82
81b. Ascospores muriform 93

82a. Ascospores with thick septa and lens-shaped lumina; disc K+ dark violet; margin orange, K+ purple ..... ***Letrouitia***
82b. Ascospores with thin septa and angular lumina; disc K–; margin not orange, K– 83

83a. Ascospores ellipsoid to oblong, 4–10 times as long as broad 84
83b. Ascospores narrowly cylindrical to filiform or acicular, 10–40 times as long as broad 90

84a. Thallus byssoid..... ***Crocynia***
84b. Thallus compact..... 85

85a. Excipulum byssoid ..... ***Byssoloma***
85b. Excipulum compact, paraplectenchymatous or incrusted with crystals. 86

86a. Conidiomata campylidia..... 87
86b. Conidiomata pycnidia or conidiomata unknown or absent 88

87a. Conidia with small lateral appendages; apothecia and campylidia with yellow to orange colors ..... ***Badimia***
87b. Conidia lacking appendages but intermingled with algal cells; apothecia and campylidia grey to brown ..... ***Tapellariopsis* (*octomera*)**

88a. Thallus dispersed into rounded patches; apothecia pink to pale red .... ***Loflammia* (*gabrielis*)**
88b. Thallus continuous; apothecia brown to almost black, rarely yellow-orange 89

89a. Apothecia with thick, white to cream-colored margin and dark brown to brownish black disc; paraphyses unbranched, distinct; excipulum incrusted with crystals ..... ***Eugeniella***
89b. Apothecia usually with thin, pale to brown margin and pale to dark brown disc; paraphyses branched and anastomosing, indistinct; excipulum mostly paraplectenchymatous, lacking crystals ..... ***Fellhanera***

90a. Excipulum paraplectenchymatous 91
90b. Excipulum prosoplectenchymatous 92

91a. Apothecia with brown disc and cream-colored margin; ascospores filiform; thallus verruculose; asci of *Byssoloma*-type..... ..... ***Brasilicia* (*brasiliensis*)**
91b. Apothecia pale yellow to orange, with evanescent margin; ascospores acicular with tapering end; thallus farinose to granulose; asci of *Bacidia*-type..... ***Bacidina***

92a. Ascospores filiform; apothecia with light to dark brown disc and cream-colored margin; asci of *Byssoloma*-type ..... ***Bapalmuia***
92b. Ascospores cylindrical to very narrowly fusiform; apothecia variously colored, mostly with yellow to orange-brown or blackish disc and margin; asci of *Bacidia*-type ..... ***Bacidia***

93a. Apothecial margin yellow to red, K+ dark purple; conidiomata pycnidia 94
93b. Apothecial margin not yellow to red, K–; conidiomata campylidia .. 95

94a. Thallus white or pale grey; apothecia pruinose; ascospores thin-walled with angular lumina..... ***Brigantiaea***
94b. Thallus yellow-green; apothecia non-pruinose; ascospores thick-walled with lens-shaped lumina ..... ***Letrouitia***

95a. Thallus continuous to irregular, pale greenish to bluish or yellowish grey, minutely farinose to verruculose; conidia ellipsoid to drop-shaped, non-septate ..... ***Sporopodium***
95b. Thallus dispersed to continuous, light to dark grey, smooth; conidia filiform, septate 96

96a. Apothecial margin pilose; thallus with wolly prothallus; conidia branched from a central point ..... ***Lasioloma***
96b. Apothecial margin smooth; thallus lacking wolly prothallus; conidia unbranched ..... ***Calopadia***

97a. Lirellae compound in (pseudo)stromata 98
97b. Lirellae solitary to sometimes aggregate but not in (pseudo)stromata 104

98a. Hymenium I+ orange-red, KI+ blue or I+ blue; ascospores with angular lumina, I– 99
98b. Hymenium I–; ascospores with lens-shaped to rounded lumina, I+ violet-blue or wine-red 101

99a. Hypothecium and excipulum colorless to dark brown, low .... ***Enterographa***
99b. Hypothecium and in part excipulum carbonized, black 100

100a. (Pseudo)stromata completely carbonized; ascospores 5-septate; with norstictic acid ..... ***Plectocarpon***
100b. (Pseudo)stromata partially carbonized below ascomata; ascospores 3-septate; lacking norstictic acid ..... ***Syncesia***

101a. Excipulum and/or hypothecium carbonized, black 102
101b. Excipulum and hypothecium colorless to brown but not carbonized 103

102a. Ascospores brown, I+ vine-red; hymenium inspers; thallus green .... ***Sarcographa***
102b. Ascospores colorless, I+violet-blue; hymenium clear; thallus yellow-brown ..... ***Glyphis* (*cicatricosa*)**

103a. Ascospores brown, I+ vine-red; disc exposed; with norstictic acid .... ***Phaeographis***
103b. Ascospores colorless, I+ violet-blue or I–; disc partially hidden beneath prominent fissurine margin; lacking norstictic acid .... ***Fissurina***

104a. Hymenium I+ orange-red, KI+ blue, rarely I+ blue; ascospores with moderately thick walls and angular lumina 105
104b. Hymenium I–; ascospores either completely thin-walled or thick-walled with lens-shaped to rounded lumina 110

105a. Ascospores muriform; hymenium lacking gelatinous matrix; lirellae C+ red ..... ***Helminthocarpon* (*leprevostii*)**
105b. Ascospores transversely septate; hymenium with gelatinous matrix; lirellae C– 106

106a. Lirellae with black or concealed or pruinose disc and carbonized, black or pruinose margin lacking algae 107
106b. Lirellae with pale brown to black, narrow disc and non-carbonized thalline margin including algae, or lirellae orange-red without distinct margin 108

107a. Lirellae non-pruinose, black ..... ***Opegrapha***
107b. Lirellae felty pruinose, grey-brown ..... ***Lecanographa* (*lyncea*)**

108a. Lirellae orange-red, without distinct margin ..... ***Coniocarpon***
108b. Lirellae with pale brown to black, narrow disc and non-carbonized thalline margin including algae 109

109a. Ascospores with acute ends ..... ***Enterographa***
109b. Ascospores with rounded ends ..... ***Sclerophyton* (*elegans*)**

110a. Ascospores completely thin-walled, with angular lumina, always I–; usually foliicolous 111
110b. Ascospores mostly thick-walled, with lens-shaped lumina, often I+ violet-blue; usually corticolous 112

111a. Apothecial margin black ..... ***Aulaxina***
111b. Apothecial margin white to pale green-grey ..... ***Calenia***

112a. Excipulum and/or hypothecium at least partly carbonized 113
112b. Excipulum and hypothecium colorless to brown but not carbonized 118

113a. Ascospores brown; hymenium strongly inspersed ..... ***Platygramme* (*caesiopruinosa*)**
113b. Ascospores colorless 114

114a. Disc exposed; thallus ecorticate, farinose 115
114b. Disc concealed; thallus corticate, smooth, rarely ecorticate 116

115a. Disc white pruinose ..... ***Diorygma***
115b. Disc chocolate brown or red ..... ***Thalloloma***

116a. Labia thickly white pruinose, C+ red ..... ***Dyplolabia***
116b. Labia non-pruinose or if white to pale yellow pruinose then C− ... 117

117a. Labia thickly white to pale yellow pruinose; ascospores usually I− .... ***Carbacanthographis***
117b. Labia non-pruinose or thinly white pruinose; ascospores I+ violet-blue ..... ***Graphis***

118a. Ascospores brown..... 119
118b. Ascospores colorless..... 120

119a. Labia thick; disc concealed..... ***Hemithecium***
119b. Labia thin; disc exposed ..... ***Phaeographis***

120a. Thallus ecorticate..... ***Diorygma***
120b. Thallus corticate 121

121a. Lirellae fissurine ..... ***Fissurina***
121b. Lirellae not fissurine..... 122

122a. Labia thick; disc concealed; ascospores more than 20 μm long..... ..... ***Hemithecium***
122b. Labia mostly thin; disc mostly exposed; ascospores less than 20 μm long 123

123a. Hymenium inspersed; with norstictic acid ..... ***Anomomorpha***
123b. Hymenium clear; with other substances or substances lacking..... ..... ***Platythecium***

124a. Ascospores brown..... 125
124b. Ascospores colourless..... 129

125a. Ascospores with thick walls and rounded lumina 126
125b. Ascospores with thin walls and angular lumina 127

126a. Ascospores mostly more than 60 μm long, with longitudinal folds in the wall; paraphyses anastomosing..... ***Architrypethelium***
126b. Ascospores mostly less than 60 μm long, lacking longitudinal folds; paraphyses simple..... ***Pyrenula***

127a. Ascospores muriform, large ..... ***Anthracothecium***
127b. Ascospores transversely septate to submuriform, small..... 128

128a. Foliicolous; ascospores 3-septate or submuriform; thallus olive to yellow-brown.....***Microtheliopsis***
128b. Corticolous; ascospores 1-septate; thallus white..... ***Mycomicrothelia***

129a. Ascospores with thick walls and diamond-shapes lumina; ascocarps often compound in pseudostromata..... 130
129b. Ascospores with thin walls and angular lumina; ascocarps usually solitary 137

130a. Ascospores transversely septate 131
130b. Ascospores muriform 135

131a. Thallus thin, white, ecorticate; perithecia solitary, exposed..... .....***Pseudopyrenula***
131b. Thallus thick, green to yellow-brown, corticate; perithecia immersed in thallus or in pseudostromata..... 132

132a. Ostioles fused to form a compound ascocarp.....***Astrothelium***
132b. Ostioles free..... 133

133a. Ascospores mostly more than 60 μm long, with longitudinal folds in the wall .....***Architrypethelium***
133b. Ascospores mostly less than 60 μm long, lacking longitudinal folds 134

134a. Paraphyses branched and anastomosing; ascus apex with narrow ring surrounding small ocular chamber; wall thickening of ascospores most pronounced at edges..... ***Trypethelium***
134b. Paraphyses unbranched; ascus apex with wide apical ring and wide ocular chamber; wall thickening of ascospore more equal..... .....***Lithothelium***

135a. Ostioles lateral, fused to other ostioles to form compound ascocarps.. ..... ***Cryptothelium***
135b. Ostioles apical, free 136

136a. Ascocarps in brown, shiny pseudostromata containing yellow or orange pigments, K– or K+ red; pseudostroma wall composed of brown, jigsaw puzzle-like hyphae .....***Bathelium***
136b. Ascocarps solitary.....***Laurera***

137a. Ascospores 1-septate, over 45 μm long, with needle-shaped crystals in the wall 138
137b. Ascospores with more than 1 septum, or if 1-septate then small and lacking crystals 139

138a. Conidiomata campylidia ..... ***Musaespora***
138b. Conidiomata pycnidia ..... ***Megalotremis***

139a. Asci completely thin-walled, with truncate tips; paraphyses unbranched 140
139b. Asci apically thick-walled, with rounded tips; paraphyses often branched and anastomosing 141

140a. Perithecia with apical setae, black ..... ***Trichothelium***
140b. Perithecia lacking setae or with scattered soft setae and then red-brown ..... ***Porina***

141a. Ascomata in compound (pseudo)stromata, resembling perithecia but actually apothecia 142
141b. Ascomata solitary, true perithecia 144

142a. Thallus byssoid ..... ***Dichosporidium***
142b. Thallus compact 143

143a. Hypothecium of individual apothecia carbonized, black; ascospores often curved ..... ***Chiodecton***
143b. Hypothecium of individual apothecia colorless to dark brown but not carbonized, low; ascospores fusiform, straight ..... ***Enterographa***

144a. Ascospores filiform-acicular ..... ***Celothelium***
144b. Ascospores cylindrical to ellipsoid 145

145a. Perithecial wall black 146
145b. Perithecial wall colorless to dark brown but not black 150

146a. Perithecia sessile, barrel-shaped, usually with apical appendages; paraphyses absent ..... ***Lyromma***
146b. Perithecia erumpent, hemispherical to conical, glabrous; paraphyses present 147

147a. Paraphyses mostly unbranched; macroconidia cylindrical, septate ..... ***Strigula***
147b. Paraphyses branched, especially above level of asci; macroconidia (sub)globose to bacillar, non-septate, or lacking 148

148a. Ascospores fusiform, 3–11-septate..... ***Polymeridium***
148b. Ascospores ovoid-fusiform, 1(–3)-septate 149

149a. Lower ascospore cell usually shorter; micro- and marcoconidia globose to ellipsoid; ostiole often lateral..... ***Anisomeridium***
149b. Lower ascospore cell usually the longer; microconidia bacillar; macroconidia lacking; ostiole always apical..... ***Arthopyrenia***

150a. Perithecia immersed in thalline warts filled with mass of fine black crystals; thallus with metallic glance..... ***Phyllobathelium***
150b. Perithecia sessile; thallus lacking metallic glance..... 151

151a. Paraphyses present; ascospores fusiform; perithecia white to grey, often with apical expansions or appendages..... ***Aspidothelium***
151b. Paraphyses absent; ascospores oblong to cylindrical; perithecia orange-brown, glabrous..... ***Phylloblastia***

152a. Conidiomata present..... 153
152b. Conidiomata absent 157

153a. Conidiomata campylidia or hyphophores..... 154
153b. Conidiomata pycnidia..... 156

154a. Conidiomata hyphophores, white with dark, arrow-shaped apex.....
..... ***Aderkomyces (heterellus)***
154b. Conidiomata campylidia..... 155

155a. Photobiont *Trentepohlia*; conidia non-septate, embedded in gelatinous matrix ..... ***Musaespora***
155b. Photobiont chlorococcoid; conidia filiform, multiseptate .....
..... ***Calopadia***, ***Tapellaria***

156a. Pycnidia hair-like, composed of long, thin tube..... ***Caprettia***
156b. Pycnidia beaked but short, with apical drops of conidial masses.....
..... ***Anisomeridium***

157a. Thallus byssoid or at least prothallus byssoid-effuse 158
157b. Thallus not byssoid..... 162

158a. Thallus distinctly byssoid 159
158b. Thallus compact but prothallus byssoid-effuse 161

159a. Thallus lacking zonate prothallus; if prothallus black then thallus appearing lobulate..... ***Crocynia***
159b. Thallus with black-and-white zonate prothallus..... 160

160a. Isidia present..... ***Dichosporidium***
160b. Isidia absent..... ***Sagenidiopsis***

161a. Isidia present; thallus thick..... ***Herpothallon***
161b. Isidia absent; thallus thin, effuse..... ***Cryptothecia***

162a. Thallus granulose-leprose..... 163
162b. Thallus compact, with maculate soralia..... 164

163a. Thallus bright yellow..... ***Chrysothrix***
163b. Thallus pale greenish to bluish grey..... ***Lepraria***

164a. Photobiont *Trentepohlia*; thallus not cartilaginous .... ***Myriotrema***, ***Ocellularia***, ***Thelotrema*** s.l.
164b. Photobiont chlorococcoid; thallus cartilaginous..... ***Pertusaria***

The genera and species

The following checklist is presented in alphabetical order, and the full set of collected specimens is cited under the name of each species. Only the name of the state and the localities are given, since all collections were made in Brazil. The numbers placed after the collector's names always refer to the first collector (M. Cáceres). Keys to species are based on data from the cited specimens and from the literature cited for each genus. No genus and species descriptions are given except for new taxa, but each genus and many species are annotated.

Acanthotrema A. Frisch (Thelotremataceae)

Notes. This genus was established by FRISCH (2006) to accommodate a single species, *Acanthotrema brasilianum*, which had formerly been placed in *Thelotrema* and *Chroodiscus*, respecticely (STAIGER & KALB 1999; STAIGER 2002), but differs from *Thelotrema* by the thin-walled ascospores and fused excipulum and from *Chroodiscus* by the spiny paraphyses tips and the presence of periphysoids. The genus *Chapsa* is also similar but has thick-walled ascospores and smooth paraphyses.

Acanthotrema brasilianum (Kalb) Frisch

Specimen examined. SERGIPE: Santa Luzia, Private property, 11° 19' S, 37° 27' W, Mata Atlântica (closed forest), *Cáceres & Lücking s.n.* (F).

Aciculopsora Aptroot (Ramalinaceae)

Notes. The genus *Aciculopsora* was erected by APTROOT *et al.* (2006) for an enigmatic species from Costa Rica with appressed squamules resting on a black prothallus, lecideine apothecia and acicular ascospores. The genus is most closely related to *Bacidiopsora* and *Squamacidia*, which both have biatorine apothecia and thicker, bacillar to cylindrical or narrowly fusiform ascospores (KALB 1988, 2004; BRAKO 1989).

Aciculopsora cinerea Cáceres & Lücking **spec. nova** (FIG. 2A–B)

Aciculopsora salmonea apotheciis cinereis et ascosporis minoribus differt. — Typus. BRAZIL. Alagoas: Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (forest along main trail), 50 m, *Cáceres A40-310a* (B, holotypus).

Description. Thallus squamulose, corticolous, 10–20 mm across and 50–100 µm thick, composed of green to olive, flat to slightly ascendent, crenate, 0.05–0.1 mm wide, closely adjacent, corticate squamules adnate to a black hypothallus, visible as black, 0.5–1 mm wide prothallus. Photobiont chlorococcoid; cells 5–8 µm diam. Apothecia sessile, rounded, 0.3–0.5 mm diam. and 150–200 µm high; disc plane, light grey; margin thick, slightly prominent, black, shiny. Excipulum prosoplectenchymatous, 50–100 µm broad, outer part consisting of thick, radiate, dark brown hyphae, inner part form by loose, irregular tissue of colorless hyphae. Hypothecium colorless to pale yellow, 20–30 µm high. Epithecium indistinct. Hymenium 30–40 µm high, colorless. Paraphyses unbranched, 1–1.5 µm thick. Asci narrowly clavate, 25–35 × 6–8 µm. Ascospores 8 per ascus, arranged in a bundle, acicular and usually curved or sigmoid, indistinctly 1–3-septate, 18–25 × 1–1.5 µm, 15–20 times as long as broad, colorless. Pycnidia not observed. Chemistry: no substances detected by TLC.

Notes. The new species differs from the type species in the smaller apothecia with grey instead of brown disc, the smaller ascospores, and the lack of a salmon-colored pigment in the apothecia. The general morphology is otherwise very similar.

Aderkomyces Bat. (Gomphillaceae)

Notes. Aderkomyces is a genus of chiefly foliicolous lichens that was recently reinstated by LÜCKING *et al.* (2005) to accommodate species formerly

placed in *Tricharia*, but with mostly white thallus setae and hyphal excipulum. One species, characterized by its long, arrow-shaped hyphophores, is commonly found both on leaves and on bark.

Aderkomyces heterellus (Stirt.) Lücking, Sérus. & Vězda (FIG. 2C)

Specimen examined. PERNAMBUCO: Cabo de Santo Agostinho, Reserva Ecológica de Gurjaú, 8° 19' S, 35° 04' W, Mata Atlântica (closed forest), 30 m, *Cáceres & Lücking 00-0142* (URM).

Ampliotrema Kalb (Thelotremataceae)

Notes. This genus was introduced recently by KALB (2004) and subsequently validated by FRISCH (2006). It is related to *Ocellularia* but differs by its prominent to sessile apothecia lacking a columella, strongly inspersed hymenium, and protocetraric acid as secondary compound. Of the five species known world-wide, two were found in the present collections.

Key to species of *Ampliotrema*

1b. Ascospores transversely septate; disc grey pruinose..... ***A. amplius***
1a. Ascospores muriform; disc yellow-pruinose..... ***A. auratum***

Ampliotrema amplius (Nyl.) Kalb (FIG. 2. D)

Specimen examined. PERNAMBUCO: Bonito, Parque Municipal de Bonito, 8° 28' S, 35°43' W, Brejo de Altitude (high altitude rainforest), 800 m, *Cáceres & Lücking 00-0269* (B, F, URM).

Ampliotrema auratum (Tuck.) Kalb

Specimen examined. SERGIPE: Santa Luzia, Private property, 11° 19' S, 37° 27' W, Mata Atlântica (closed forest), *Cáceres & Lücking 00-0901* (B, F, URM).

Anisomeridium (Müll. Arg.) Choisy (Monoblastiaceae)

Notes. Anisomeridium is a large genus of more than 100 species world-wide, characterized by mostly thin thalli with *Trentepohlia* photobiont and black perithecia (HARRIS 1995). The strongly anastomosing paraphyses, the relatively broad, ovoid ascospores, and the broad macroconidia embedded in a gelatinous matrix separate this genus from similar *Strigula* species. Five species were found in the present material, including one undescribed taxon with pycnidia only.

Key to species of *Anisomeridium*

perithecia absent.....
.....***Anisomeridium*** spec.

1b. Pycnidia rare; thallus white-grey; perithecia present 2

2a. Perithecia with lateral ostiole; microconidia elliptical (2.5 × 1.5 µm), or microconidia unknown..... 3

2b. Perithecia with apical ostiole; microconidia globose (2.0 × 2.0 µm)... 4

3a. Ascospores granular ornamented, 26–42 × 7–12 µm; microconida not seen.....***A. americanum***

3b. Ascospores smooth, 23–29 × 7–8 µm; microconidia elliptical, 2.5 × 1.5 µm.....***A. polycarpum***

4a. Ascospores 18–28 × 9–14 µm.....***A. leptospermum***

4b. Ascospores 15–24 × 4.5–6 µm.....***A. tamarindii***

Anisomeridium americanum (A. Massal.) R. C. Harris (FIG. 2E)

Specimens examined. ALAGOAS: Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (forest along main trail), 50 m, *Cáceres A32-251* (F). SERGIPE: Santa Luzia, Private property, 11° 19' S, 37° 27' W, Mata Atlântica (closed forest), *Cáceres & Lücking 00-0820* (B, F, URM), *00-0859* (B, F, URM), *00-0888* (B-600124223, F), *00-0889* (B-600124224, F).

Anisomeridium leptospermum (Zahlbr.) R. C. Harris

Specimen examined. PERNAMBUCO: Caruaru, Brejo dos Cavalos, 8° 20' S, 35° 58' W, Brejo de Altitude (high altitude rainforest), 800–900 m, *Cáceres & Lücking 00-0633* (ABL, B-600124001, F).

Anisomeridium polycarpum (Müll. Arg.) R. C. Harris

Specimen examined. ALAGOAS: Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (forest along main trail), 50 m, *Cáceres A46-420* (B, F).

Anisomeridium tamarindii (Fée) R. C. Harris (FIG. 2F)

Specimen examined. PERNAMBUCO: Caruaru, Instituto Pernambucano de Pesquisas Agropecuárias (IPA), 8° 17' S, 35° 58' W, Caatinga (open thornbush), 500–600 m, *Cáceres & Lücking 00-0040* (B-600124002, F).

Anisomeridium spec. (FIG. 2G)

Notes. This material cannot be assigned to any known species since it is only represented by abundant pycnidia. The pycnidia are clearly beaked and produce large drops of conidia on top.

Specimens examined. ALAGOAS: Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro (systematic sampling), 09° 37' S, 35° 58' W, Mata Atlântica (forest along main trail), 50 m, *Cáceres A32-249* (B, F), *A32-250* (URM).

Anomomorpha Nyl. (Graphidaceae)

Notes. This genus was reinstated by STAIGER (2002) to include Graphidaceae with non-carbonized excipulum, exposed disc, inspersed hymenium, and colorless, small ascospores. *Platythecium* is similar but can be distinguished by the clear hymenium, among other features. One species was found in the present material. A further species, *A. sordida* Staiger, was reported from Bahia (Staiger 2002).

Anomomorpha aggregans (Nyl.) Staiger (FIG. 2H)

Specimens examined. PERNAMBUCO: Igarassu, Refúgio Ecológico Charles Darwin, 7° 50' S, 34° 54' W, Mata Atlântica (closed forest), 20 m, *Cáceres & Lücking 00-0527* (B), *00-0531* (F), *00-0530* (URM).

Anthracothecium A. Massal. (Pyrenulaceae)

Notes. The genus *Anthracothecium* comprises species with mostly large, black perithecia (often covered by thallus tissue), unbranched paraphyses, and muriform, dark brown, thin-walled ascospores (HARRIS 1989, 1995). The genus lacks a modern revision.

Key to species of *Anthracothecium*

1a. Ascomata 0.6-1.0 mm in diam.; ascospores 140–175 × 33–40 µm ....***A. duplicans***

1b. Ascomata 1.0-1.8 mm in diam.; ascospores 60–90 × 25–35 µm ....***A. prasinum***

Anthracothecium duplicans (Nyl.) Müll. Arg. (FIG. 3A)

Specimen examined. PERNAMBUCO: Caruaru, Instituto Pernambucano de Pesquisas Agropecuárias (IPA), 8° 17' S, 35° 58' W, Caatinga (open thornbush), 500–600 m, *Cáceres & Lücking 00-0029* (B-600124003, F).

Anthracothecium prasinum (Eschw.) R. C. Harris (FIG. 3B)

Specimen examined. RIO GRANDE DO NORTE: Baía Formosa, Reserva Particular do Patrimônio Natural (RPPN) Mata Estrela Senador Antônio Farias, 06° 22' S, 35° 01' W, Mata Atlântica (closed forest), 0 m, *Cáceres 01-0187* (B-600124173, F, URM).

Architrypethelium Aptroot (Trypetheliaceae)

Notes. Architrypethelium is similar to certain species of *Trypethelium* and *Astrothelium* but differs by its very large ascospores which are brown when mature, a rare feature in the family (APTROOT 1991). Especially young ascospores of *A. uberinum*, however, remain colorless for a long time and then resemble those of *Trypethelium* except for their size and longitudinal folds in the wall.

Architrypethelium uberinum (Fée) Aptroot

Specimen examined. PERNAMBUCO: Caruaru, Brejo dos Cavalos, 8° 20' S, 35° 58' W, Brejo de Altitude (high altitude rainforest), 800–900 m, *Cáceres & Lücking 00-0602* (F).

Arthonia Ach. (Arthoniaceae)

Notes. This large, mostly tropical genus is in urgent need of revision (GRUBE 1998; SUNDIN & TEHLER 1998). As applied in this work, *Arthonia* includes species with applanate, emarginate ascomata, hemiamyloid hymenium, strongly branched paraphyses and more or less macrocephalic, rarely isolocular, transversely septate to muriform ascospores. The genus is more or less easily recognized in the field by the dark, spot-like, often large ascomata, but no modern treatment at the species level exists and therefore types were studied in the herbaria of G (Fée, Müller Argoviensis), H (Acharius, Nylander), S (Malme, Redinger), and TUR (Vainio). Species with muriform ascospores are included in *Arthonia* when ascomata morphology agreed with the species with transversely septate ascospores.

Key to species of *Arthonia*

1a. Ascospores transversely septate 2
1b. Ascospores submuriform to muriform 11

2a. Ascospores 1-septate 3
2b. Ascospores 2–15-septate 5

3a. Apothecia angular-lobate; ascospores oblong, 8–12 × 2.5–3 µm ..... ***A. microsperma***
3b. Apothecia round; ascospores drop-shaped, 6–10 × 2–3 µm 4

4a. Apothecia brown ..... ***A. leptosperma***

4b. Apothecia purple-pruinose ..... ***A.*** aff. ***leptosperma***

5a. Ascospores 2-septate, 9–12 × 3–4 µm..... ***A.*** aff. ***microsperma***
5b. Ascospores 3–15-septate, longer 6

6a. Ascospores up to 5-septate 7
6b. Ascospore (5–)7–15-septate 10

7a. Ascospores 3–5-septate; apothecia light brown to purple-black 8
7b. Ascospores 5–septate; apothecia black 9

8a. Apothecia lirellate, light brown; ascospores colorless, 25–30 × 10–12 µm..... ***A.*** aff. ***polygramma***
8b. Apothecia angular-rounded, purple-black; ascospores brown, ornamented, 20–25 × 7–8 µm..... ***A.*** aff. ***complanata***

9a. Apothecia angular; ascospores pale brown ..... ***A.*** aff. ***circumalbicans***
9b. Apothecia angular-rounded; ascospores colorless..... ***A. complanata***

10a. Apothecia lobate-lirellate, purple-brown; ascospores 5–7-septate, fusiform, 17–22 × 5-7 µm ..... ***A.*** cf. ***subvelata***
10b. Apothecia angular-rounded, black; ascospores 15-septate, oblong-fusiform, 55–75 × 12–18 µm..... ***A. platygraphidea***

11a. Apothecia lobate-lirellate; ascospores submuriform, 25–28 × 7–8 µm . ..... ***A.*** aff. ***interveniens***
11b. Apothecia angular-rounded; ascospores muriform, longer 12

12a. Apothecia black with white marginal zone; ascospores 50–65 × 15–22 µm, pale brown..... ***A.*** aff. ***bessalis***
12b. Apothecia brown to black; ascospores colorless 13

13a. Apothecia brown; ascospores 60–75 × 20–25 µm ..... ***A. andamanica***
13b. Apothecia black; ascospores 30–50 × 12–17 µm..... ***A. bessalis***

Arthonia andamanica (Makhija & Patw.) Cáceres & Lücking **comb. nova**

Arthothelium andamanicum Makhija & Patw., *Journal of the Hattori Botanical Laboratory* **78**: 202. 1995.

Notes. This taxon is here recombined in *Arthonia* since its ascoma morphology and anatomy perfectly agrees with the bulk of tropical *Arthonia* species, showing that ascospore septation is not a good character to separate

genera. The brown rather than black ascomata also separate this taxon from most of the other species found here.

Specimens examined. SERGIPE: Itabi, Private property, 10° 06' S, 37° 54' W, Caatinga (thornbush), 100 m, *Cáceres 2186* (F, URM), *2191* (F).

Arthonia bessalis Nyl. (FIG. 3C)

Specimens examined. ALAGOAS: Barra de São Miguel, Reserva Particular do Patrimônio Natural (RPPN) Rosa do Sol, 09° 51' S, 35° 53' W, Mata Atlântica (closed forest), 50 m, *Cáceres 01-0132* (F, URM). Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (forest along main trail), 50 m, *Cáceres A04-025* (B, URM), *A43-338a* (URM), *A45-362* (F), *A45-365* (F), *A45-366b* (F). PERNAMBUCO: Igarassu, Refúgio Ecológico Charles Darwin, 7° 50' S, 34° 54' W, Mata Atlântica (closed forest), 20 m, *Cáceres & Lücking 00-0490* (F). RIO GRANDE DO NORTE: Baía Formosa, Reserva Particular do Patrimônio Natural (RPPN) Mata Estrela Senador Antônio Farias, 06° 22' S, 35° 01' W, Mata Atlântica (closed forest), 0 m, *Cáceres 01-0174* (F, URM).

Arthonia aff. ***bessalis*** Nyl.

Notes. No name was found for this very characteristic species. Its ascomata resemble those of *Arthonia circumalbicans* (AWASTHI 1991), which has much smaller, transversely septate ascospores. *A. bessalis* differs by the absence of a white margin around the ascomata and the smaller, hyaline ascospores.

Specimen examined. ALAGOAS: Barra de São Miguel, Reserva Particular do Patrimônio Natural (RPPN) Rosa do Sol, 09° 51' S, 35° 53' W, Mata Atlântica (closed forest), 50 m, *Cáceres 01-0146* (F).

Arthonia aff. ***circumalbicans*** Nyl.

Notes. According to AWASTHI (1991), the material agrees with the paleotropical *Arthonia circumalbicans* in the angular to almost lobate ascomata and brownish, 3–5-septate ascospores, but lacks the white ascoma margin characteristic for that species.

Specimens examined. PERNAMBUCO: Igarassu, Refúgio Ecológico Charles Darwin, 7° 50' S, 34° 54' W, Mata Atlântica (closed forest), 20 m, *Cáceres & Lücking 00-0499* (F), *00-0412* (URM).

Arthonia complanata Fée (FIG. 3D)

Specimens examined. ALAGOAS: Barra de São Miguel, Reserva Particular do Patrimônio Natural (RPPN) Rosa do Sol, 09° 51' S, 35° 53' W, Mata Atlântica (closed forest), 50 m, *Cáceres 01-0145* (B), *01-0155* (F, URM). PERNAMBUCO: Cabo de Santo Agostinho, Reserva Ecológica de Gurjaú, 8° 19' S, 35° 04' W, secondary vegetation (open area), 30 m, *Cáce-*

res & Lücking 00-0235 (F). Igarassu, Refúgio Ecológico Charles Darwin, 7° 50' S, 34° 54' W, Mata Atlântica (closed forest), 20 m, *Cáceres & Lücking 00-0485* (B, F), *00-0487* (B, F), *00-0489* (F), *00-0486* (URM), *00-0488* (URM).

Arthonia aff. ***complanata*** Fée

Notes. The material agrees with *Arthonia complanata* in all aspects, except that the ascospores are brown and ornamented.

Specimens examined. ALAGOAS: Barra de São Miguel, Reserva Particular do Patrimônio Natural (RPPN) Rosa do Sol, 09° 51' S, 35° 53' W, Mata Atlântica (closed forest), 50 m, *M. Cáceres 01-0149* (F). PERNAMBUCO: Caruaru, Instituto Pernambucano de Pesquisas Agropecuárias (IPA), 8° 17' S, 35° 58' W, Caatinga (open thornbush), 500–600 m, *Cáceres & Lücking 00-0021* (F, URM).

Arthonia aff. ***interveniens*** Nyl. (FIG. 3F)

Notes. Arthonia interveniens Nyl. has similar ascospores but regularly rounded ascomata. *Arthothelium nigrescens* Makhija & Patw. agrees in ascomata shape but has broader ascospores and differs in other anatomical features.

Specimen examined. ALAGOAS: Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (forest along main trail), 50 m, *Cáceres A45-364* (F).

Arthonia leptosperma (Müll. Arg.) R. Sant.

Specimens examined. ALAGOAS: Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (closed forest), 50 m, *Cáceres & Lücking 01-0070* (F).

Arthonia aff. ***leptosperma*** (Müll. Arg.) R. Sant.

Notes. This taxon is similar to *Arthonia leptosperma* in ascospore type but has purplish pruinose ascomata, a feature not known from the preceeding species.

Specimen examined. PERNAMBUCO: Bonito, Parque Municipal de Bonito, 8° 28' S, 35°43' W, Brejo de Altitude (high altitude rainforest), 800 m, *Cáceres & Lücking 00-0300* (F).

Arthonia microsperma Müll. Arg.
Notes. The paleotropical *Arthonia dispersula* Nyl. (AWASTHI 1991) is close to this species or probably even an older name.

Specimens examined. PERNAMBUCO: São Lourenço da Mata, Estação Ecológica de Tapacurá, 8° 02' S, 35° 09' W, Agreste (open dry forest), 100 m, *Cáceres & Lücking 98-0250* (B, F).

Arthonia aff. ***microsperma*** Müll. Arg. (FIG. 3G)

Notes. Ascomata and ascospores are of the same size as in *Arthonia microsperma* but ascospores are regularly 2-septate and macrocephalic instead of 1-septate and isolocular.

Specimen examined. ALAGOAS: Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (closed forest), 50 m, *Cáceres s.n.* (F).

Arthonia platygraphidea Nyl. (FIG. 3H)

Specimen examined. PERNAMBUCO: Cabo de Santo Agostinho, Reserva Ecológica de Gurjaú, 8° 19' S, 35° 04' W, secondary vegetation (open area), 30 m, *Cáceres & Lücking 00-0236* (B, F).

Arthonia *aff.* ***polygramma*** Nyl. (FIG. 3E)

Notes. Arthonia polygramma Nyl. is very similar but has smaller ascospores (17–22 μm long) and darker ascomata covered by a whitish pruina.

Specimen examined. PERNAMBUCO: Cabo de Santo Agostinho, Reserva Ecológica de Gurjaú, 8° 19' S, 35° 04' W, Mata Atlântica (closed forest), 30 m, *Cáceres & Lücking 00-0225* (F).

Arthonia cf. ***subvelata*** Nyl.

Notes. The material agrees well with the type, especially in the small, lobate-lirellate ascomata, except that the ascospores are slightly larger and more septate (13–18 μm, 3–5-septate in *Arthonia subvelata*).

Specimens examined. PERNAMBUCO: Garanhuns, secondary Caatinga vegetation, *Cáceres & Lücking 98-0521* (F).

Arthopyrenia A. Massal. **(**Arthopyreniaceae)

Notes. The genus *Arthopyrenia* superficially resembles *Anisomeridium* and *Strigula* in many aspects and differs mostly in subtle characters such as hamathecium structure and micro- and macroconidia, which are not always present, however (HARRIS 1995). All three commonly have thin, white to grey thalli associated with a *Trentepohlia* photobiont, and 1-septate, thin-walled ascospores are dominant. As a rule of thumb, *Strigula* has unbranched paraphyses while those of *Anisomeridium* and *Arthopyrenia* are branched and anastomosing. The latter two differ by hamathecial and conidial characters but also by their ascospores, with the proximal cell often smaller

in *Anisomeridium* but larger in *Arthopyrenia*. Molecular studies indicate that all three belong in Dothideomycetes, but their exact position remains unresolved (DEL PRADO *et al.* 2006; JAMES *et al.* 2006). Only one common species was found in the present collections.

Arthopyrenia cinchonae (Ach.) Müll. Arg. (FIG. 4A)

Specimens examined. SERGIPE: Gararu, 9° 58' S, 37° 54' W, Caatinga (thornbush), 0–100 m, *Cáceres 2107* (B, F, URM), *2106a* (F).

Arthothelium A. Massal. (Arthoniaceae)

Notes. TEHLER (1995) suggested to exclude the type species of *Arthothelium* from the Arthoniales, but this has not been confirmed so far by molecular methods and the genus has since been continued to be included in Arthoniaceae (TEHLER 1996; GRUBE 1998). *Arthothelium* is here used to include species with prominent ascomata that produce the asci in irregular fashion in distinct locules within a relative compact, stromatic tissue, unlike *Arthonia* where the asci and paraphyses form a hymenial layer (GRUBE 1998). Traditionally, *Arthothelium* included all species with muriform ascospores, but many of these are more closely related to *Arthonia* species (see above). On the other hand, one taxon was found with transversely septate ascospores but ascomata of the *Arthothelium* type and is here treated within that genus. Because of the lack of a modern revision, working names have been used for the species distinguished here.

Key to species of *Arthothelium*

1a. Ascospores transversely septate, 70–80 µm long.....***A.*** spec.
1b. Ascospores muriform, 50–65 µm long..... 2

2a. Ascomata thinly pruinose; ascospores 60–65 µm long.....
.....***A.*** aff. ***chiodectoides***
2b. Ascomata non-pruinose; ascospores 45–55 µm long..***A.*** aff. ***spectabile***

Arthothelium aff. ***spectabile*** Flot. ex A. Massal. (FIG. 4C)

Notes. The material fits this taxon well, except that the ascospores are too large on average.

Specimen examined. PERNAMBUCO: Cabo de Santo Agostinho, Reserva Ecológica de Gurjaú, 8° 19' S, 35° 04' W, Mata Atlântica (closed forest), 30 m, *Cáceres & Lücking 00-0188* (F).

Arthothelium aff. ***chiodectoides*** (Nyl.) Zahlbr.

Notes. No name was found for this rather abundant species. The paleotropical *Arthothelium chiodectoides* comes close but has distinctly smaller ascospores (AWASTHI 1991).

Specimens examined. ALAGOAS: Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (forest along main trail), 50 m, *M. Cáceres A03-023* (B, F, URM), *A04-028* (URM), *A43-343* (B, F).

Arthothelium spec. (FIG. 4B)

Notes. The ascospores of this species resemble those of *Arthonia platygraphidea*, but the ascoma anatomy is different and points to a close relationship with *Arthothelium* s.str.

Specimens examined. SERGIPE: Santa Luzia, Private property, 11° 19' S, 37° 27' W, Mata Atlântica (closed forest), *Cáceres & Lücking 00-0822* (F, URM), *00-0824* (F).

Aspidothelium Vain. (Thelenellaceae)

Notes. Species of *Aspidothelium* typically have white to pale grey or pink perithecia, often with apical appendages (SANTESSON 1952). The ascospores are fusiform and have very thin cells, a type of ascospores not found in other pyrenocarpous lichens. The species are mostly foliicolous but rarely also found on bark. The genus was synonymized with *Thelenella* by HARRIS (1995) but reinstated by LÜCKING (1998) as part of the family Thelenellaceae. *Thelenella* itself has been shown to be closely related to the Ostropales (SCHMITT *et al.* 2005), but no molecular data exist so far for *Aspidothelium*.

Aspidothelium geminiparum (Malme) R. Sant. (FIG. 4D)

Specimens examined. PERNAMBUCO: Caruaru, Brejo dos Cavalos, 8° 20' S, 35° 58' W, Brejo de Altitude (high altitude rainforest), 800–900 m, *Cáceres & Lücking 00-0609f* (F), *00-0676c* (F).

Astrothelium Eschw. (Trypetheliaceae)

Notes. Astrothelium conforms one of the core groups of Trypetheliaceae in the Dothideomycetes (HARRIS 1986, 1995; DEL PRADO *et al.* 2006). Traditionally it includes species in which several perithecia are aggregated in a thallus wart (pseudostroma) and share a common ostiole by fusion of the ostiolar channels. However, correlation with other characters indicate that such 'astrothelioid morphs' do not form a natural group but rather evolved independently from different groups within the Trypetheliaceae (HARRIS 1995).

Key to species of *Astrothelium*

1a. Pseudostromata with yellow-orange, K+ purple pigment 2
1b. Pseudostromata white, K– 3

2a. Hymenium inspersed; ascospores fusiform, 25–35 × 7–10 µm ..... ***A. cinnamomeum***
2b. Hymenium clear; ascospores ellipsoid, 35–42 × 10–13 µm..... ***A. scorioides***

3a. Ascospores predominantly 5-septate ..... ***A. eustomum***
3b. Ascospores 3-septate 4

4a. Ascospores 20–25 × 7–10 µm ..... ***A. variolosum***
4b. Ascospores 35–40 × 10–13 µm ..... ***A.*** aff. ***leucothelium***

Astrothelium cinnamomeum (Eschw.) Müll. Arg.

Specimens examined. PERNAMBUCO: Bonito, Parque Municipal de Bonito, 8° 28' S, 35°43' W, Brejo de Altitude (high altitude rainforest), 800 m, *Cáceres & Lücking 00-0312* (B-600124004, F), *00-0314* (B-600124005, URM).

Astrothelium eustomum (Mont.) Müll. Arg. (FIG. 4E)

Specimen examined. SERGIPE: Areia Branca, Reserva Ecológica Serra de Itabaiana, 10° 45' S, 37° 20' W, Mata Atlântica (closed forest), 500 m, *M. Cáceres 2076* (ABL, B, F, URM).

Astrothelium aff. ***leucothelium*** Nyl. (FIG. 4F)

Specimen examined. PERNAMBUCO: Bonito, Parque Municipal de Bonito, 8° 28' S, 35°43' W, Brejo de Altitude (high altitude rainforest), 800 m, *Cáceres & Lücking 00-0313* (B-600124007, F).

Astrothelium scorioides Nyl. (FIG. 4G)

Specimen examined. PERNAMBUCO: Bonito, Parque Municipal de Bonito, 8° 28' S, 35°43' W, Brejo de Altitude (high altitude rainforest), 800 m, *Cáceres & Lücking 00-0296* (B-600124006, F).

Astrothelium variolosum (Ach.) Müll. Arg. (FIG. 4H)

Specimens examined. ALAGOAS: Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (forest along main trail), 50 m, *Cáceres A43-341* (B, F, URM).

Bacidia De Not. (Ramalinaceae)

Notes. *Bacidia* was redefined by EKMAN (1996), who monographed the North American species, to include only species with crustose thallus, biatorine (rarely lecideine) apothecia, prosoplectenchymatous excipulum, *Bacidia*-type ascus, and narrowly fusiform to acicular, multiseptate ascospores. No modern monograph for tropical species exists, but the present material could be identified using both EKMAN (1996) and MALME (1935).

Key to species of *Bacidia*

1a. Thallus squamulose; ascospores short fusiform, 3-septate..... .....***Bacidia*** spec.
1b. Thallus crustose; ascospores long fusiform, (3–)5–25-septate..... 2

1a. Apothecial margin indistinct; hypothecium colorless; epithecium indistinct; ascospores 3–5-septate, 25–35 × 2–3 µm, 10–13 times as long as broad.....***Bacidia medialis***
1b. Apothecial margin distinct; hypothecium and epithecium colored; ascospores 7–25-septate, 45–80 × 2–5 µm, 15–25 times as long as broad 2

2a. Ascospores 7-septate, 45–65 × 2–3 µm, 20–25 times as long as broad .....***B. russeola***
2b. Ascospores 15–25-septate, 60–80 × 3–5 µm, 15–20 times as long as broad ..... ***B. fluminensis***

Bacidia fluminensis (Malme) Cáceres & Lücking **comb. et stat. nova** (FIG. 5A)

Bacidia millegrana f. *fluminensis* Malme, *Arkiv Bot.* **27A(5):** 22. 1935.

Notes. The present material fits *Bacidia millegrana* (Taylor) Zahlbr. in morphology and anatomy but has consistently larger ascospores. Such specimens were also described from Rio de Janeiro by MALME (1935) and separated as f. *fluminensis*, and the taxon is here raised to species level.

Specimens examined. PERNAMBUCO: Caruaru, Brejo dos Cavalos, 8° 20' S, 35° 58' W, Brejo de Altitude (high altitude rainforest), 800–900 m, *Cáceres & Lücking 00-0570* (F), *00-0572* (B, F), *00-0573* (F), *00-0571* (URM), *00-0585* (URM).

Bacidia medialis (Tuck.) Zahlbr. (FIG. 5B)

Specimens examined. PERNAMBUCO: Caruaru, Instituto Pernambucano de Pesquisas Agropecuárias (IPA), 8° 17' S, 35° 58' W, Caatinga (open thornbush), 500–600 m, *Cáceres & Lücking 00-0076* (B, F, URM), *00-0077* (F), *00-0108b* (F).

Bacidia russeola (Kremp.) Zahlbr. (FIG. 5C)

Specimens examined. PERNAMBUCO: Caruaru, Instituto Pernambucano de Pesquisas Agropecuárias (IPA), 8° 17' S, 35° 58' W, Caatinga (open thornbush), 500–600 m, *Cáceres & Lücking 00-0106* (F), *00-0057* (URM), *00-0104* (URM). SERGIPE: Itabi, Private property, 10° 06' S, 37° 54' W, Caatinga (thornbush), 100 m, *M. Cáceres 2162* (B, F), *2175* (B, F, URM).

Bacidia spec.

Specimen examined. PERNAMBUCO: Cabo de Santo Agostinho, Reserva Ecológica de Gurjaú (Barragem), 8° 19' S, 35° 04' W, Mata Atlântica (closed forest), 30 m, *Cáceres & Lücking 98-s.n.* (B, F, URM).

Bacidina Vězda (Ramalinaceae)

Notes. This genus is very similar and closely related to *Bacidia* but differs mainly in the paraplectenchymatous instead of prosoplectenchymatous excipulum, the consistently acicular, very narrow, tapering ascospores, and the mostly pale yellow to orange, very rarely brown apothecia (VĚZDA 1990; EKMAN 1996). The thallus is typically granular to microsquamulose.

Key to species of *Bacidina*

1a. Apothecia grey; anamorph hyphomycetous, producing abundant, mold-like sporodochia ..... ***B. penicillata***
1b. Apothecia pale yellow to orange; anamorph pycnidial 2

2a. Ascospores 7–11-septate ..... ***B. multiseptata***
2b. Ascospores 3–7-septate 3

3a. Ascospores 3–4 µm wide ..... ***B.*** aff. ***varia***
3b. Ascospores 1–2.5 µm wide 4

4a. Pycnidia abundant, up to 0.2 mm high; apothecia irregularly crenulate, with persistent, cream-colored margin ..... ***B. digitalis***
4b. Pycnidia rare, up to 0.15 mm high; apothecia regularly rounded, with evanescent margin of same color as disc 5

5a. Ascospores 40–60 × 1-1.5 µm ..... ***B. pallidocarnea***
5b. Ascospores 25–40 × 1.5-2.5 µm ..... ***B. varia***

Bacidina digitalis Cáceres & Lücking **spec. nova** (FIG. 5D)

Bacidina apiahica apotheciis marginibus persistentibus et pycnidiis maioribus differt. — Typus. ALAGOAS: Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (forest along main trail), 50 m, *Cáceres A29-243* (URM, holotypus; B, F, isotypi). — Paratypus. Same locality, *Cáceres A29-242b* (B).

Description. Thallus crustose, corticolous, continuous, 20–50 mm across and 30–50 µm thick, granulose, olive green. Photobiont chlorococcoid, cells 5–8 µm diam., in 30-50 µm large goniocysts. Apothecia sessile, rounded but soon irregularly crenulate, 0.3–0.5 mm diam. and 150–200 µm high; disc slightly convex, yellow; margin thin but persistent, cream-colored. Excipulum paraplectenchymatous with radiating cell rows, 30–50 µm broad. Hypothecium 15–30 µm high, colorless to pale yellow. Epithecium indistinct. Hymenium 40–60 µm high, colorless. Paraphyses unbranched, 1 µm thick. Asci narrowly clavate, 35–50 × 6–8 µm. Ascospores arranged in a bundle, filiform but tapering towards proximal end, (3–)7-septate, 30–40 × 1.2–1.5 µm, 25–30 times as long as broad. Pycnidia abundant, sessile, tubular, conical to finger-like, 0.15–0.2 mm high and 70–100 µm wide at base, cream-colored; wall formed by densely intricate, apically parallel hyphae. Conidia filiform, straight to slightly curved, indistinctly 7–11-septate, 50–60 × 0.8–1 µm. Chemistry: no substances detected by TLC.

Notes. This new species is characterized by its conspicuous, abundant, finger-like pycnidia producing filiform conidia. Similar pycnidia have been found *in Bacidina apiahica*, but in that species they are smaller (SANTESSON 1952; LÜCKING 2007). In addition, the irregularly crenulate apothecia with persistent, cream-colored margin, in combination with the finally 7-septate ascospores, distinguish *B. digitalis* from the typically foliicolous *B. apiahica*.

Bacidina multiseptata Cáceres & Lücking **spec. nova** (FIG. 5E)

Bacidina pallidocarnea ascosporis maioribus differt. — Typus. PERNAMBUCO: Caruaru, Brejo dos Cavalos, 8° 20' S, 35° 58' W, Brejo de Altitude (high altitude rainforest), 800–900 m, *Cáceres & Lücking 00-0543* (URM, holotypus). — Paratypi. PERNAMBUCO: Igarassu, Refúgio Ecológico Charles Darwin, 7° 50' S, 34° 54' W, Mata Atlântica (closed forest), 20 m, *Cáceres & Lücking 00-0455* (B), *00-0459b* (F).

Description. Thallus crustose, corticolous, continuous, 10–20 mm across and 15–25 µm thick, farinose to granulose, green. Photobiont chlorococcoid, cells 5–10 µm diam. Apothecia sessile, rounded, 0.3–0.5 mm diam. and 150–220 µm high; disc plane to slighty convex, pale yellow; margin thin, often evanescent, of the same color as the disc or paler. Excipulum paraplectenchymatous, 30–70 µm broad. Hypothecium 20–40 µm high,

colorless to pale yellow. Epithecium indistinct. Hymenium 70–90 µm high, colorless. Paraphyses unbranched, 1 µm thick. Asci narrowly clavate, 65–85 × 8–10 µm. Ascospores arranged in a bundle, filiform but tapering towards proximal end, (7–)11-septate, 50–80 × 1.2–1.8 µm, 30–45 times as long as broad. Pycnidia not observed. Chemistry: no substances detected by TLC.

Notes. Bacidina multiseptata is very similar and closely related to *B. apiahica* and *B. pallidocarnea*, which are chiefly foliicolous taxa. All three species are virtually impossible to distinguish externally, differing basically in their ascospore septation and length. *B. apiahica* have (1–)3-septate, 20–40 µm long ascospores while those of *B. pallidocarnea* are (3–)7-septate and 40–60 µm in length. *Bacidina multiseptata* is thus a further sporomorph in this series of taxa. According to the description given by MALME (1935), *Bacidia carneolutea* Malme fits the present material, except for the excipulum "... *ex hyphis formata radiantibus* ...", which points to *Bacidia* s.str. instead. The type was examined and indeed proved to be a genuine *Bacidia*, although its ascospores are unusually narrow for that genus. It differs from *Bacidina multiseptata* in the thicker, grey thallus and distinctly marginate apothecia with prosoplectenchymatous excipulum.

Bacidina pallidocarnea (Müll. Arg.) Vězda

Specimens examined. ALAGOAS: Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (forest along main trail), 50 m, *M. Cáceres A05-cortex* (F). PERNAMBUCO: Bonito, Parque Municipal de Bonito, 8° 28' S, 35°43' W, Brejo de Altitude (high altitude rainforest), 800 m, *Cáceres & Lücking 00-0343* (URM).

Bacidina penicillata Aptroot, Cáceres, Lücking & Sparrius (FIG. 5F)

Specimens examined. ALAGOAS: Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (closed forest), 50 m, *Cáceres & Lücking 01-0156* (URM). PERNAMBUCO: Caruaru, Brejo dos Cavalos, 8° 20' S, 35° 58' W, Brejo de Altitude (high altitude rainforest), 800–900 m, *Cáceres & Lücking 00-0538* (F).

Bacidina varia S. Ekman

Specimen examined. ALAGOAS: Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (forest along main trail), 50 m, *M. Cáceres A11-cortex sample* (F).

Bacidina aff. ***varia*** S. Ekman

Notes. The material differs from *Bacidina varia* by the broader ascospores; it is probably undescribed.

Specimen examined. ALAGOAS: Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (forest along main trail), 50 m, *M. Cáceres A33-257* (F).

Bacidiopsora Kalb (Ramalinaceae)

Notes. Bacidiopsora is closely related to *Bacidia* and agrees with the latter in apothecial and chemical characters, but differs in its more elaborated, squamulose thallus (KALB 1988, 2004; EKMAN 1996). *Phyllopsora* is similar in thallus structure but its apothecia have a different anatomy and its ascospores are small and non-septate.

Key to species of *Bacidiopsora*

1a. Thallus microphyllous; thallus lobes dissected, marginally ornamented with many small lobules ..... ***B. microphyllina***
1b. Thallus lobes not microphyllous; thallus tightly adnate to a whitish prothallus, with cylindrical isidia ..... ***B. oryzabana***

Bacidiopsora microphyllina Kalb

Specimen examined. SERGIPE: Santa Luzia, Private property, 11° 19' S, 37° 27' W, Mata Atlântica (closed forest), *Cáceres & Lücking s.n.* (B, URM).

Bacidiopsora orizabana (Vain.) Kalb (FIG. 5G)

Specimen examined. SERGIPE: Ribeira, Mata Atlântica, *M. Cáceres 2042* (B, F, URM).

Bactrospora A. Massal. (Roccellaceae)

Notes. The genus *Bactrospora* was monographed by EGEA & TORRENTE (1994). It is characterized by black, rounded apothecia with an often irregular surface and anatomically by its cylindrical ascospores which often have a strong constriction at the middle. The thallus is usually thin and often makes the impression of being non-lichenized.

Key to species of *Bactrospora*

1a. Ascospores 40–65 × 4–5 µm, up to 8–13-septate ..... ***B. jenikii***
1b. Ascospores longer, more than 13–29-septate 2

2a. Ascospores narrow, 50–85(–90) × 2–3.5 µm, 13-21-septate ..... ***B. myriadea***
2b. Ascospores broad, (60–)70–95 × 6–10 µm, 19–29-septate ..... ***B. macrospora***

Bactrospora jenikii (Vězda) Egea & Torrente

Specimen examined. PERNAMBUCO: Cabo de Santo Agostinho, Reserva Ecológica de Gurjaú, 8° 19' S, 35° 04' W, Mata Atlântica (closed forest), 30 m, *Cáceres & Lücking 00-0229* (F).

Bactrospora macrospora R. C. Harris

Specimen examined. ALAGOAS: Barra de São Miguel, Reserva Particular do Patrimônio Natural (RPPN) Rosa do Sol, 09° 51' S, 35° 53' W, Mata Atlântica (closed forest), 50 m, *M. Cáceres 01-0151* (B-600124265, F, URM).

Bactrospora myriadea (Fée) Egea & Torrente (FIG. 5H)

Specimens examined. PERNAMBUCO: Caruaru, Instituto Pernambucano de Pesquisas Agropecuárias (IPA), 8° 17' S, 35° 58' W, Caatinga (open thornbush), 500–600 m, *Cáceres & Lücking 00-0130a* (F), *00-0131a* (B). Recife, Dois Irmãos, Mata Atlântica (closed forest), *Cáceres & Lücking 98-0522* (URM). Recife, Universidade Federal de Pernambuco (UFPE), secondary vegetation on campus, *Cáceres & Lücking 98-s.n.* (B, F, URM).

Baculifera Marbach & Kalb (Physciaceae)

Notes. In an attempt to provide a more natural classification of the artificial genus *Buellia* in the tropics, MARBACH (2000) introduced several new genera to accommodate smaller species groups. Among these, *Baculifera* is a rather non-descript genus characterized by ascospores with weak endospore thickenings, bacillar conidia, a commonly present black prothallus, and a clear hymenium. Most similar is *Hafellia*, but that genus has stronger endospore thickenings, slightly different conidia, lacks a black prothallus and has an inspersed hymenium. The distinction of both genera is obscured by the genus *Cratiria*, which in many aspects is intermediate, but usually features a three-layered excipulum.

Key to species of *Baculifera*

1a. Apothecia pruinose; ascospores coarsely ornamented .... ***B. endochlora***
1b. Apothecia non-pruinose; ascospores smooth to finely ornamented ..... ***B. pseudomicromera***

Baculifera endochlora (J. Steiner) Marbach (FIG. 6A)

Specimen examined. PERNAMBUCO: Garanhuns, secondary Caatinga vegetation, *Cáceres & Lücking 98-0500b* (F).

Baculifera pseudomicromera Marbach (FIG. 6B)

Specimens examined. PERNAMBUCO: Caruaru, Brejo dos Cavalos, 8° 20' S, 35° 58' W, Brejo de Altitude (high altitude rainforest), 800–900 m, *Cáceres & Lücking 00-0661* (URM). Caruaru, Instituto Pernambucano de Pesquisas Agropecuárias (IPA), 8° 17' S, 35° 58' W, Caatinga (open thornbush), 500–600 m, *Cáceres & Lücking 00-0069* (F), *00-0072* (B-600124104, F, URM), *00-0073* (F), *00-0074* (B-600124008, F). SERGIPE: Gararu, 9° 58' S, 37° 54' W, Caatinga (thornbush), 0–100 m, *M. Cáceres 2095* (B, F, URM), *2127* (F), *2149c* (F). Itabi, Private property, 10° 06' S, 37° 54' W, Caatinga (thornbush), 100 m, *M. Cáceres 2168* (F).

Bapalmuia Sérus. (Pilocarpaceae)

Notes. This genus is characterized by small to rather large, brown to black apothecia with often strongly convex disc and evanescent margin, and very narrow asci producing acicular to filiform, multiseptate ascospores (SÉRUSIAUX 1993; EKMAN 1996; KALB *et al.* 2000). *Bapalmuia* can be distinguished from *Bacidia* and *Bacidina* by the *Byssoloma*-type ascus, which is, however, very difficult to observe. Other distinguishing characters are the smooth to effuse thallus (never granulose), the brown to black apothecia with strongly convex disc, and the very long and narrow, multiseptate ascospores.

Key to species of *Bapalmuia*

1a. Apothecial margin persistent; excipulum labyrinthic; ascospores 19–29-septate, 70–105 × 2–3 µm ..... ***B. halleana***
1b. Apothecial margin evanescent; excipulum radiate; ascospores 25–50-septate, up to 150 µm long 2

2a. Ascospores 25–35-septate, 70–120 × 1.5–2.5 µm..... ***B. palmularis***
2b. Ascospores 35–50-septate, 85–150 × 2.5–3.5 µm..... ***B. lafayetteana***

Bapalmuia halleana Sérus. (FIG. 6C)

Specimens examined. ALAGOAS: Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (closed forest), 50 m, *Cáceres & Lücking 01-0038* (F, URM), *01-0041* (URM), *01-0062* (F), *01-0064* (B), *01-0078* (F), *01-0079* (B, F, URM), *01-0107* (F), *01-0109* (F, URM), *01-0119* (F), *01-0122* (B, F), *01-0158* (B), *01-0530* (B, F). Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (forest along main trail), 50 m, *M. Cáceres A25-213b* (F).

Bapalmuia lafayetteana (Vain.) Kalb & Lücking (FIG. 6D)

Specimens examined. ALAGOAS: Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (forest along main trail), 50 m, *Cáceres A16-142* (B), *A20-181* (F).

Bapalmuia palmularis Müll. Arg.) Sérus.

Specimens examined. ALAGOAS: Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (closed forest), 50 m, *Cáceres & Lücking 01-0092* (URM), *01-0502* (F), *01-0532* (B).

Bathelium Ach. (Trypetheliaceae)

Notes. Species of *Bathelium* were traditionally included in either *Trypethelium* (ascospores transversely septate) or *Laurera* (ascospores muriform), but a more natural concept unites under *Bathelium* taxa with perithecia that are aggregate in brown pseudostromata filled with anthraquinone pigments and are covered by a cortical layer formed by jigsaw-shaped cells (HARRIS 1995). The genus thus defined includes several common species with both transversely septate and muriform ascospores, but only the latter were found in the present material.

Key to species of *Bathelium*

1a. Ascospores 40–50 µm long ..... ***B. madreporiforme***
1b. Ascospores 50–80 µm long ..... ***B. mastoideum***

Bathelium madreporiforme (Eschw.) Trevis. (FIG. 6E)

Specimens examined. ALAGOAS: Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (closed forest), 50 m, *Cáceres 2021* (F). PERNAMBUCO: São Lourenço da Mata, Estação Ecológica de Tapacurá, 8° 02' S, 35° 09' W, Agreste (open dry forest), 100 m, *Cáceres & Lücking 98-0258* (B-600124279, F, URM).

Bathelium mastoideum Afz. ex Ach.

Specimen examined. ALAGOAS: Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (closed forest), 50 m, *Cáceres & Lücking 01-0511* (F).

Brigantiaea Trevis. (Brigantiaeaceae)

Notes. Species of this genus are usually conspicuous by their large, yellow-orange apothecia producing large, muriform ascospores (HAFELLNER 1997). Most similar is the genus *Letrouitia*, but that genus differs by its thallus color (yellow-green instead of white) and the ascospores producing distinct endospore thickenings. In the Neotropics, there is only one common and widespread species.

Brigantiaea leucoxantha (Spreng.) R. Sant. & Haf. (FIG. 6F)

Specimen examined. PERNAMBUCO: Cabo de Santo Agostinho, Reserva Ecológica de Gurjaú, 8° 19' S, 35° 04' W, Mata Atlântica (closed forest), 30 m, *Cáceres & Lücking 00-0574* (B-600124149, F, URM).

Byssoloma Trevis. (Pilocarpaceae)

Notes. Most species of *Byssoloma* grow on leaves but several taxa are ubiquitous in their substrate preferences and can also be found abundantly on bark (SANTESSON 1952; HARRIS 1995; LÜCKING 2007). The species usually resemble tiny *Bacidias* but are clearly distinguished by their byssoid apothecial margin and the *Byssoloma*-type ascus.

Key to species of *Byssoloma*

1a. Ascospores 7-septate ..... ***B. vanderystii***
1b. Ascospores 3-septate 2

2a. Excipulum reduced; disc color yellow-brown; thallus brown..... ..... ***B.*** aff. ***meadii***
2b. Excipulum well-developed; disc color black-brown or grey-brown.... 3

3a. Disc color black brown; thallus farinose, green ..... ***B. chlorinum***
3b. Disc color grey-black; thallus smooth-cracked, grey-green..... ..... ***B. leucoblepharum***

Byssoloma chlorinum (Vain.) Zahlbr.

Specimens examined. PERNAMBUCO: Bonito, Parque Municipal de Bonito, 8° 28' S, 35°43' W, Brejo de Altitude (high altitude rainforest), 800 m, *Cáceres & Lücking 00-0333b* (F). Caruaru, Brejo dos Cavalos, 8° 20' S, 35° 58' W, Brejo de Altitude (high altitude rainforest), 800–900 m, *Cáceres & Lücking 00-0599c* (B-600124028), *00-0609e* (F).

Byssoloma leucoblepharum (Nyl.) Vain. (FIG. 6G)

Specimens examined. PERNAMBUCO: Bonito, Parque Municipal de Bonito, 8° 28' S, 35°43' W, Brejo de Altitude (high altitude rainforest), 800 m, *Cáceres & Lücking 00-0277b* (F), *00-0333a* (F), *00-0609c* (F), *00-0676b* (F).

Byssoloma aff. ***meadii*** (Tuck.) S. Ekman

Notes. The material agrees with *Byssoloma meadii* in all characters of apothecial and thallus morphology, but the thallus lacks xanthones and is UV–. The yellow-brown apothecial disc and thin, cream-colored margin, as well as the brown thallus, separate this material from *B. leucoblepharum*.

Specimens examined. PERNAMBUCO: Bonito, Parque Municipal de Bonito, 8° 28' S, 35°43' W, Brejo de Altitude (high altitude rainforest), 800 m, *Cáceres & Lücking 00-0333c* (F). Caruaru, Brejo dos Cavalos, 8° 20' S, 35° 58' W, Brejo de Altitude (high altitude rainforest), 800–900 m, *Cáceres & Lücking 00-0599d* (B-600124028), *00-0609d* (F), *00-0660* (F). Igarassu, Refúgio Ecológico Charles Darwin, 7° 50' S, 34° 54' W, Mata Atlântica (closed forest), 20 m, *Cáceres & Lücking 00-0397* (F).

Byssoloma vanderystii Sérus. (FIG. 6H)

Specimens examined. ALAGOAS: Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (forest along main trail), 50 m, *Cáceres A16-141* (B, F), *A16-147* (F), *A36-cortex* (F).

Calopadia Vězda (Ectolechiaceae)

Notes. Like the preceeding genus, species of *Calopadia* are more commonly found on leaves but are not unfrequent on bark either. They can usually be distinguished by their grey-brown to black apothecia and large, muriform ascospores (KALB & VĚZDA 1987; LÜCKING 1999). The characteristic campylidia are rarely observed in corticolous material.

Key to species of *Calopadia*

1a. Ascospores 2–4 per ascus ..... ***C. foliicola***
1b. Ascospores 1 per ascus 2

2a. Ascospores 80–110 × 20–30 µm 3
2b. Ascospores 50–80 × 20–30 µm 4

3a. Apothecia young white pruinose ..... ***C. bonitensis***
3b. Apothecia cream-pruinose ..... ***C. perpallida***

4a. Apothecia black; hypothecium aeruginous ..... ***C. subcoerulescens***
4b. Apothecia other colored; hypothecium brown *5*

5a. Apothecia cream-pruinose ..... ***C. pruinosa***
5b. Apothecia grey-brown ..... ***C. puiggarii***

Calopadia bonitensis Cáceres & Lücking **spec. nova** (FIG. 7A–B)

Calopadia subfusca apotheciis pro parte pruinosis differt. — Typus. PERNAMBUCO: Bonito, Parque Municipal de Bonito, 8° 28' S, 35°43' W, Brejo de Altitude (high altitude rainforest), 800 m, *Cáceres & Lücking 00-0337* (URM, holotypus; B-600124011, F, isotypi).

Description. Thallus crustose, corticolous, continuous but with irregular areas lacking algae, up to 50 mm across and 30–40 µm thick, ecorticate, smooth to uneven, white-grey. Photobiont chlorococcoid; cells 5–7 µm diam. Apothecia sessile, rounded, 0.4–0.7 mm diam. and 250–350 µm high; disc plane, brown to dark brown; margin distinct, prominent, light grey-brown; young and immature apothecia usually with a distinct, coarse, white pruina. Excipulum 50–100 µm broad, colorless to slightly brownish. Hypothecium 30–60 µm high, brown. Apothecial base yellow-brown. Hymenium 130–180 µm high, colorless. Paraphyses mostly unbranched, 1–1.5 µm thick. Asci 120–160 × 25–35 µm. Ascospores single, oblong, muriform, 80–110 × 20–30 µm, 3.5–4 times as long as broad, colorless; postmature ascospores often transforming into pycnidia within the ascus; conidia ellipsoid to fusiform, non-septate, 2–3 × 0.5–0.7 µm. Campylidia ear-shaped, with indistinct base and large lobe, 0.7–1 mm high and wide, dark grey. Wall paraplectenchymatous, partly aeruginous to sordid green. Conidia filiform, 7–11-septate, 70–90 × 1.5–2 µm, colorless. Chemistry: no substances detected by TLC.

Notes. This new species is a typical *Calopadia*, as obvious from the combination of brown apothecia with paraplectenchymatous excipulum, brown hypothecium, mostly unbranched paraphyses, muriform ascospores, and grey campylidia with large lobe producing filiform, multiseptate conidia. Its most characteristic feature is the coarse, white pruina on young and immature apothecia (both disc and upper margin). The single, relatively long ascospores indicate close relationship with *C. subfusca* Kalb & Vězda and *C. perpallida* (Nyl.) Vezda. The first one has non-pruinose apothecia with thinner, non-prominent margin and aeruginous apothecial base, which the second one features apothecia that are persistently covered with a thick, cream-colored pruina.

Calopadia foliicola (Fée) Vězda

Specimen examined. PERNAMBUCO: Bonito, Parque Municipal de Bonito, 8° 28' S, 35°43' W, Brejo de Altitude (high altitude rainforest), 800 m, *Cáceres & Lücking 00-0697* (F).

Calopadia perpallida (Nyl.) Vězda

Specimen examined. PERNAMBUCO: Bonito, Parque Municipal de Bonito, 8° 28' S, 35°43' W, Brejo de Altitude (high altitude rainforest), 800 m, *Cáceres & Lücking 00-0338* (F).

Calopadia pruinosa Lücking & Chaves

Specimens examined. PERNAMBUCO: Bonito, Parque Municipal de Bonito, 8° 28' S, 35°43' W, Brejo de Altitude (high altitude rainforest), 800 m, *Cáceres & Lücking 00-0339* (F).

Caruaru, Brejo dos Cavalos, 8° 20' S, 35° 58' W, Brejo de Altitude (high altitude rainforest), 800–900 m, *Cáceres & Lücking 00-0671* (URM).

Calopadia puiggarii (Müll. Arg.) Vězda

Specimens examined. PERNAMBUCO: Bonito, Parque Municipal de Bonito, 8° 28' S, 35°43' W, Brejo de Altitude (high altitude rainforest), 800 m, *Cáceres & Lücking 00-0340* (F). São Lourenço da Mata, Estação Ecológica de Tapacurá, 8° 02' S, 35° 09' W, Agreste (open dry forest), 100 m, *Cáceres & Lücking 98-0252* (URM).

Calopadia subcoerulescens (Zahlbr.) Vězda (FIG. 7B)

Specimens examined. PERNAMBUCO: Cabo de Santo Agostinho, Barragem, Mata Atlântica, *Cáceres & Lücking s.n.* (F). Recife, Dois Irmãos, Mata Atlântica (closed forest), *Cáceres & Lücking 98-0519* (URM).

Candelaria A. Massal. (Candelariaceae)

Notes. Species of *Candelaria* are readily recognized by their small-foliose thalli with yellow, K– pigment (pulvinic acids). The family was previously included in Lecanorales but has now been shown to fall outside the Lecanoromycetidae and probably deserves its own subclass (MIADLIKOWSKA *et al*. 2006).

Candelaria concolor (Dicks.) Stein

Specimen examined. PERNAMBUCO: Caruaru, Brejo dos Cavalos, 8° 20' S, 35° 58' W, secondary (fence posts), 800–900 m, *Cáceres & Lücking 00-0801b* (F).

Caprettia Bat. & H. Maia (Monoblastiaceae)

Notes. Caprettia is one of the few lichen genera described by the Brazilian mycologist Batista and his co-workers (BATISTA & MAIA 1965) that survived a recent critical revision (LÜCKING *et al.* 1998). The genus is characterized by its long-tubular, hair-like pycnidia. In a monographic treatment, SÉRUXIAUX & LÜCKING (2003) suggested that *Caprettia* also included species with perithecioid ascomata, thus making it possible to place the genus in Monoblastiaceae close to *Anisomeridium*. However, this view was opposed by VĚZDA (2004), who established the separate genus *Porinella* R. Sant. for the species with perithecia.

Caprettia amazonensis Bat. & H. Maia (FIG. 7D)

Specimen examined. PERNAMBUCO: Cabo de Santo Agostinho, Reserva Ecológica de Gurjaú, 8° 19' S, 35° 04' W, secondary vegetation (open area), 30 m, *Cáceres & Lücking 00-0221* (B, F, URM).

Carbacanthographis Staiger & Kalb (Graphidaceae)

Notes. This recently established genus (STAIGER 2002) is most similar to *Graphis* in having well-developed labia that conceal the disc and a strongly carbonized excipulum. However, the ascospores are non-amyloid, the excipulum produces partly spiny periphysoids, and also the chemistry is slightly different compared to *Graphis*. In general, species of *Carbacanthographis* can also be recognized by their strongly white-pruinose lirellae, similar to the genus *Dyplolabia*, but that genus produces lecanorid acid (lirellae C+ red) and lacks spiny periphysoids.

Key to species of *Carbacanthographis*

1a. Excipulum basally open; ascospores 8 per ascus, 12–17 × 5–7 µm; secondary chemistry salazinic acid..... ***C. marcescens***
1b. Excipulum basally closed; ascospores 1 or 8 per ascus, longer; secondary chemistry stictic acid 2

2a. Ascospores 9–13-septate, 25–35 × 5-7 µm ..... ***C. stictica***
2b. Ascospores muriform, 120–180 × 25–30 µm..... ***C. crassa***

Carbacanthographis crassa (Müll. Arg.) Staiger & Kalb

Specimen examined. SERGIPE: Areia Branca, Reserva Ecológica Serra de Itabaiana, 10° 45' S, 37° 20' W, Mata Atlântica (closed forest), 500 m, *Cáceres & Lücking 2207* (B, F, URM).

Carbacanthographis marcescens (Fée) Staiger & Kalb (FIG. 7E)

Specimen examined. RIO GRANDE DO NORTE: Baía Formosa, Reserva Particular do Patrimônio Natural (RPPN) Mata Estrela Senador Antônio Farias, 06° 22' S, 35° 01' W, Mata Atlântica (closed forest), 0 m, *Cáceres 01-0168* (B, F).

Carbacanthographis stictica Staiger & Kalb (FIG. 7F)

Specimen examined. SERGIPE: Santa Luzia, Private property, 11° 19' S, 37° 27' W, Mata Atlântica (closed forest), *Cáceres & Lücking 00-0840* (B, F).

Catillaria A. Massal. (Catillariaceae)

Notes. The genus *Catillaria* s.lat. traditionally included all species of Lecanorales with crustose thallus, biatorine to lecideine apothecia, and 1-septate ascospores. In the course of a modern circumscription, many species have been excluded from the genus and placed elsewhere, such as in *Catinaria*, *Fellhanera*, and *Megalaria* (KILIAS 1981; HAFELLNER 1984; EKMAN

& TØNSBERG 1996; GALLOWAY *et al.* 2005). Yet, the differences between *Catillaria* s.str., *Catinaria*, and *Megalaria*, such as ascus type and apothecial pigments, are not always readily observed, and thus far no monographic treatments exist for most of the tropical taxa.

Key to species of *Catillaria*

1a. Isidia present..... ***C.*** spec. A
1b. Isidia absent..... ***C.*** spec. B

Catillaria spec. A (FIG. 7G)

Notes. The material closely resembles *Catinaria isidiza* (Makhija & Nagarkar) Sipman in thallus and apothecial morphology, but has much smaller ascospores in numbers of 8 per ascus, which place it in *Catillaria* s.lat.

Specimen examined. ALAGOAS: Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (closed forest), 50 m, *Cáceres & Lücking 01-0555* (F).

Catillaria spec. B (FIG. 7H)

Specimen examined. ALAGOAS: Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (closed forest), 50 m, *Cáceres & Lücking 01-535* (F).

Celothelium A. Massal. (Pyrenulaceae)

Notes. Celothelium is rather unique and easily recognized among lichenized pyrenocarpous ascomycetes due to its long-filiform ascospores. The systematic placement of this genus was unclear until most recently, and HARRIS (1995) placed it in Thelenellaceae in lack of better options. However, a molecular phylogenetic study (DEL PRADO *et al.* 2006) showed that *Celothelium* is sister to *Pyrenula* and thus can be accommodated in the Pyrenulaceae, although the branches separating them are rather long and *Celothelium* perhaps deserves its own family within the Pyrenulales.

Celothelium aciculiferum (Nyl.) Vain. (FIG. 8A)

Specimens examined. PERNAMBUCO: Bonito, Parque Municipal de Bonito, 8° 28' S, 35°43' W, Brejo de Altitude (high altitude rainforest), 800 m, *Cáceres & Lücking 00-0302* (B-600124010). Igarassu, Refúgio Ecológico Charles Darwin, 7° 50' S, 34° 54' W, Mata Atlântica (closed forest), 20 m, *Cáceres & Lücking 00-0394* (F), *00-0411* (URM).

Chapsa A. Massal. (Thelotremataceae)

Notes. The genus *Chapsa* was reinstated by FRISCH (2006) to accommodate Thelotremataceae with chroodiscoid apothecia but more or less thick-walled ascospores and presence of periphysoids. The genus is most closely related to *Thelotrema* (FRISCH *et al.* 2006b), but that genus has convergent apothecial margins and there is a characteristic split between the excipulum and then thalline margin ('double margin').

Key to species of *Chapsa*

1a. Ascomata with dark red pigment on disc ..... ***C. punicea***
1b. Disc not pigmented 2

2a. Ascospores transversely septate 3
2b. Ascospores submuriform to muriform 10

3a. Ascospores 3–9-septate 4
3b. Ascospores 15–35 septate 8

4a. Ascospores 3-septate, brown; apothecial margin felty ..... ***C. leprieurii***
4b. Ascospores 3–9-septate, colorless; apothecial margin not felty 5

5a. Ascospores 3–5-septate 6
5b. Ascospores 5–9-septate 7

6a. Ascospores thick-walled, 10–18 × 3–5 µm; disc white pruinose; apothecial margin mealy ..... ***C. astroidea***
6b. Ascospores thin-walled, 12–16 × 4–5 µm; disc blue-white pruinose; apothecial margin smooth ..... ***C. platycarpella***

7a. Ascospores thick-walled, 15–25 × 5–8 µm; apothecia round to lirellate, large; stictic acid ..... ***C. dilatata***
7b. Ascospores thin-walled, 17–22 × 4–5 µm; apothecia angular-rounded, small; no substances ..... ***C. alborosella***

8a. Ascospores 19–35-septate; apothecial disc crystalline-pruinose ..... ***C. indica***
8b. Ascospores 15–19-septate; apothecial disc non-pruinose 9

9a. Ascospores 2–4 per ascus, 60–120 × 10–15 µm; stictic acid ..... ***C. sublilacina***
9b. Ascospores 4–8 per ascus, 30–50 × 5–7 µm; no substances ..... ***C.*** aff. ***sublilacina***

10a. Ascospores 4–8 per ascus, 30–40 μm long; disc white pruinose 11
10b. Ascospores 1 per ascus, 60–160 μm long; disc felty 12

11a. Ascospores 8 per ascus, submuriform, 30–35 × 8–10 μm ..... ***C. velata***
11b. Ascospores 4-8 per ascus, muriform, 35–40 × 10–12 μm..... ..... ***C. leprocarpoides***

12a. Ascospores 60–110 × 20–40 μm; apothecial margin erect to recurved . ..... ***C. leprocarpa***
12b. Ascospores 90–160 × 25–35 μm; apothecial margin incurved to erect, multiple..... ***C. patens***

Chapsa alborosella (Nyl.) A. Frisch (FIG. 8B)

Specimens examined. ALAGOAS: Barra de São Miguel, Reserva Particular do Patrimônio Natural (RPPN) Rosa do Sol, 09° 51' S, 35° 53' W, Mata Atlântica (closed forest), 50 m, *Cáceres 01-0138* (URM), *01-0139* (B, F). Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (forest along main trail), 50 m, *Cáceres A08-066* (F).

Chapsa astroidea (Berk. & Broome) Cáceres & Lücking **comb. nova**

Platygrapha astroidea Berk. & Broome, *J. Linn. Soc.*, Bot., **14:** 109. 1875; *Ocellularia astroidea* (Berk. & Broome) Hale, *Mycotaxon* **7:** 377. 1978; *Thelotrema astroideum* (Berk. & Broome) Hale, *Mycotaxon* **11:** 131. 1980.

Specimens examined. SERGIPE: Santa Luzia, Private property, 11° 19' S, 37° 27' W, Mata Atlântica (closed forest), *Cáceres & Lücking 00-0838a* (F).

Chapsa dilatata (Müll. Arg.) Kalb (FIG. 8C)

Specimens examined. ALAGOAS: Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (closed forest), 50 m, *Cáceres 2069* (F, URM), *2070* (F), *2073* (URM). Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (forest along main trail), 50 m, *Cáceres A10-093* (F). PERNAMBUCO: Bonito, Parque Municipal de Bonito, 8° 28' S, 35°43' W, Brejo de Altitude (high altitude rainforest), 800 m, *Cáceres & Lücking 00-0327* (F, URM). Cabo de Santo Agostinho, Reserva Ecológica de Gurjaú, 8° 19' S, 35° 04' W, Mata Atlântica (closed forest), 30 m, *Cáceres & Lücking 00-0183* (F). Caruaru, Brejo dos Cavalos, 8° 20' S, 35° 58' W, Brejo de Altitude (high altitude rainforest), 800–900 m, *Cáceres & Lücking 00-0617* (B-600124195, F). Igarassu, Refúgio Ecológico Charles Darwin, 7° 50' S, 34° 54' W, Mata Atlântica (closed forest), 20 m, *Cáceres & Lücking 00-0432* (B-600124096, F), *00-0433* (hb. Kalb). SERGIPE: Areia Branca, Reserva Ecológica Serra de Itabaiana, 10° 45' S, 37° 20' W, Mata Atlântica (closed forest), 500 m, *A. Aptroot 2077* (URM), *Cáceres & Lücking 2204* (F, URM). Santa Luzia, Private property, 11° 19' S, 37° 27' W, Mata Atlântica (closed forest), *Cáceres & Lücking 00-0841* (F), *00-0842* (F), *00-0847* (F), *00-0858* (F), *00-0860* (B, F, URM), *00-0862* (F).

Chapsa indica A. Massal. (FIG. 8D)

Specimens examined. ALAGOAS: Barra de São Miguel, Reserva Particular do Patrimônio Natural (RPPN) Rosa do Sol, 09° 51' S, 35° 53' W, Mata Atlântica (closed forest), 50 m, *Cáceres 01-0139* (F), *01-0142* (F).

Chapsa leprieurii (Mont.) A. Frisch (FIG. 8E)

Specimen examined. PERNAMBUCO: Igarassu, Refúgio Ecológico Charles Darwin, 7° 50' S, 34° 54' W, Mata Atlântica (closed forest), 20 m, *Cáceres & Lücking 00-0431* (B, F, URM).

Chapsa leprocarpa (Nyl.) A. Frisch

Specimens examined. PERNAMBUCO: Caruaru, Brejo dos Cavalos, 8° 20' S, 35° 58' W, Brejo de Altitude (high altitude rainforest), 800–900 m, *Cáceres & Lücking 00-0614* (URM), *00-0635* (B, F, URM).

Chapsa leprocarpoides (Hale) Cáceres & Lücking comb. nova

Thelotrema leprocarpoides Hale, *Bull. Br. Mus. Nat. Hist. (Bot.)* **8(3):** 259. 1981.

Specimens examined. PERNAMBUCO: Igarassu, Refúgio Ecológico Charles Darwin, 7° 50' S, 34° 54' W, Mata Atlântica (closed forest), 20 m, *Cáceres & Lücking 00-0429* (URM). Caruaru, Instituto Pernambucano de Pesquisas Agropecuárias (IPA), 8° 17' S, 35° 58' W, Caatinga (open thornbush), 500–600 m, *Cáceres & Lücking 00-0033* (B). SERGIPE: Gararu, 9° 58' S, 37° 54' W, Caatinga (thornbush), 0–100 m, *Cáceres 2143* (F, URM), *2151b* (F, URM), *s.n.* (F), *s.n.* (URM).

Chapsa patens (Nyl.) A. Frisch (FIG. 8F)

Specimens examined. ALAGOAS: Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (closed forest), 50 m, *Cáceres & Lücking 01-0529a* (F).

Chapsa platycarpella (Vain.) A. Frisch (FIG. 8G)

Specimens examined. PERNAMBUCO: Bonito, Parque Municipal de Bonito, 8° 28' S, 35°43' W, Brejo de Altitude (high altitude rainforest), 800 m, *Cáceres & Lücking 00-0325* (F), *00-0326* (URM), *00-0328* (B-600124196, F, URM), *00-0329* (B-600124197, F), *00-0330* (URM). Cabo de Santo Agostinho, Reserva Ecológica de Gurjaú, 8° 19' S, 35° 04' W, Mata Atlântica (closed forest), 30 m, *Cáceres & Lücking 00-0184* (F). Caruaru, Brejo dos Cavalos, 8° 20' S, 35° 58' W, Brejo de Altitude (high altitude rainforest), 800–900 m, *Cáceres & Lücking 00-0547* (F, URM). Igarassu, Refúgio Ecológico Charles Darwin, 7° 50' S, 34° 54' W, Mata Atlântica (closed forest), 20 m, *Cáceres & Lücking 00-0425* (F, URM), *00-0426* (B, F), *00-0427* (F), *00-0428* (URM), *00-0430* (B-600124089). RIO GRANDE DO NORTE: Baía Formosa, Reserva Particular do Patrimônio Natural (RPPN) Mata Estrela Senador Antônio Farias, 06° 22' S, 35° 01' W, Mata Atlântica (closed forest), 0 m, *Cáceres 01-0188* (B-600124277, URM). SERGIPE: Areia Branca, Reserva Ecológica Serra de Itabaiana, 10° 45' S, 37° 20' W, Mata Atlântica (closed forest), 500 m, *Cáceres & Lücking*

2205 (F, URM). Santa Luzia, Private property, 11° 19' S, 37° 27' W, Mata Atlântica (closed forest), *Cáceres & Lücking 00-0844* (F, URM).

Chapsa punicea (Müll. Arg.) Cáceres & Lücking comb. nova

Arthothelium puniceum Müll. Arg., *Hedwigia* **32:** 133. 1893; *Thelotrema puniceum* (Müll. Arg.) Makhija & Patw., *Trop. Bryol.* **10:** 213. 1995.

Specimens examined. ALAGOAS: Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (forest along main trail), 50 m, *Cáceres A10-099* (F). PERNAMBUCO: Bonito, Parque Municipal de Bonito, 8° 28' S, 35°43' W, Brejo de Altitude (high altitude rainforest), 800 m, *Cáceres & Lücking 00-0263* (B, F. URM).

Chapsa sublilacina (Ellis & Everh.) Cáceres & Lücking comb. nova (FIG. 8H)

Karstenia sublilacina Ellis & Everh., *Bull. Iowa Lab. Nat. Hist.* **4:** 69. 1896; *Thelotrema sublilacinum* (Ellis & Everh.) Vain., *Proc. Amer. Acad. Arts Sci.* **58:** 137. 1923; *Ocellularia sublilacina* (Ellis & Everh.) Zahlbr., *Catalogus Lichenum Universalis* **2:** 601. 1923.

Specimen examined. PERNAMBUCO: Bonito, Parque Municipal de Bonito, 8° 28' S, 35°43' W, Brejo de Altitude (high altitude rainforest), 800 m, *Cáceres & Lücking 00-0288* (F).

Chapsa aff. ***sublilacina*** (Ellis & Everh.) Cáceres & Lücking

Specimen examined. SERGIPE: Santa Luzia, Private property, 11° 19' S, 37° 27' W, Mata Atlântica (closed forest), *Cáceres & Lücking 00-0826* (F, URM).

Chapsa velata (Müll. Arg.) Cáceres & Lücking comb. nova

Thelotrema velatum Müll. Arg., *Bulletin de la Société Botanique Belgique* **32:** 147. 1893.

Specimen examined. PERNAMBUCO: Caruaru, Brejo dos Cavalos, 8° 20' S, 35° 58' W, Brejo de Altitude (high altitude rainforest), 800–900 m, *Cáceres & Lücking 00-0608* (F).

Chiodecton Ach. (Roccellaceae)

Notes. The genus *Chiodecton* is characterized by its perithecioid ascomata aggregated in partially carbonized stromata (THOR 1990; GRUBE 1998). The stromata externally resemble the pseudostromata of certain pyrenocarpous lichens, such as *Bathelium* and *Trypethelium*, but the hamathecium and ascus structure and the ascospores immediately reveal the true relationships of *Chiodecton* with other genera in the Roccellaceae. *Dichosporidium* has similar ascomata but differs by its byssoid thallus.

Chiodecton malmei G. Thor (FIG. 9A)

Specimens examined. ALAGOAS: Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (forest along main trail), 50 m, *Cáceres A03-024* (B, F), *A04-34a* (F), *A43-336* (URM).

Chrysothrix J. R. Laundon (Arthoniaceae)

Notes. The genus *Chrysothrix* comprises *Lepraria*-like lichens with pulvinic acid derivates as secondary compounds and thus having bright yellow colors (LAUNDON 1981; GRUBE 1998; KALB 2001). Many species are sterile or rarely produce apothecia and then are easily confused with species of *Candelariella*. The latter, however, have a more distinctly granulose thallus and only contain calycin as secondary substance.

Key to species of *Chrysothrix*

1a. Thallus sulphur yellow; vulpinic acid present..... ***C. chlorina***
1b. Thallus bright yellow; vulpinic acid absent..... 2

2a. Major substance calycin; granules up to 200 μm in diam. ***C. candelaris***
2b. Major substance pinastric acid; granules up to 50 μm in diam. ..... ***C. xanthina***

Chrysothrix candelaris (L.) J. R. Laundon

Specimen examined. SERGIPE: Gararu, 9° 58' S, 37° 54' W, Caatinga (thornbush), 0–100 m, *Cáceres 2100* (F).

Chrysothrix chlorina (Ach.) J. R. Laundon (FIG. 9B)

Specimen examined. ALAGOAS: Barra de São Miguel, Reserva Particular do Patrimônio Natural (RPPN) Rosa do Sol, 09° 51' S, 35° 53' W, Mata Atlântica (closed forest), 50 m, *Cáceres 01-0137* (B, F).

Chrysothrix xanthina (Vain.) Kalb

Specimen examined. PERNAMBUCO: Caruaru, Instituto Pernambucano de Pesquisas Agropecuárias (IPA), 8° 17' S, 35° 58' W, Caatinga (open thornbush), 500–600 m, *Cáceres & Lücking 00-0093b* (F).

Coccocarpia Pers. (Coccocarpiaceae)

Notes. Coccocarpia is one of the few microfoliose genera treated here. The genus is easily recognized by its dark grey color caused by the cyanobacterial photobiont (*Scytonema*), and by the rhizinate apothecia (ARVIDSSON 1983; LÜCKING *et al.* 2007).

Key to species of *Coccocarpia*

1a. Lobes narrowly flabellate, marginally with branched phyllidia..... .....***C. microphyllina***
1b. Lobes broadly flabellate, laminally with abundant, genuine isidia ....***C. palmicola***

Coccocarpia microphyllina Lücking & Aptroot

Specimen examined. ALAGOAS: Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (forest along main trail), 50 m, *Cáceres A37-287c* (F).

Coccocarpia palmicola (Spreng.) Arv. & D. J. Galloway (FIG. 9C)

Specimen examined. PERNAMBUCO: Cabo de Santo Agostinho, Reserva Ecológica de Gurjaú, 8° 19' S, 35° 04' W, Mata Atlântica (closed forest), 30 m, *Cáceres & Lücking 00-0143* (B).

Coenogonium Ehrenb. (Coenogoniaceae)

Notes. The genus *Coenogonium* was recently redefined to include species with both filamentous and crustose thalli, thus synonymizing the name *Dimerella* with *Coenogonium* (LÜCKING & KALB 2000). This view has been controversely discussed (VĚZDA 2004), but was supported by a phenotype-based phylogenetic analysis (RIVAS PLATA *et al.* 2006). Apparently, the filamentous taxa form several, unrelated lineages nested within the bulk of crustose species. The genus is particularly speciose in the study area and more species are expected to be found.

Key to species of *Coenogonium*

1a. Thallus filamentous; algal cells moniliform or cylindrical 2
1b. Thallus crustose; algal cells angular-rounded 7

2a. Algal cells moniliform; thallus appressed filamentous .... ***C. moniliforme***
2b. Algal cells cylindrical; thallus not appressed 3

3a. Thallus shelf-like, projecting from substrate, semicircular 4
3b. Thallus prostrate, adnate to substrate, irregular..... 6

4a. Ascospores non-septate ..... ***C. leprieurii***
4b. Ascospores 1-septate 5

5a. Apothecial margin denticulate..... ***C. confervoides***
5b. Apothecial margin smooth ..... ***C. linkii***

6a. Ascospores 5–10 μm long ..... ***C. interplexum***
6b. Ascospores 10–14 μm long ..... ***C. disjunctum***

7a. Isidia present; apothecia pale yellow-brown ..... ***C. isidiosum***
7b. Isidia absent; apothecia differently colored..... 8

8a. Apothecial margin pilose..... ***C. barbatellum***
8b. Apothecial margin smooth, denticulate or uneven, but not pilose 9

9a. Apothecial disc bright yellow..... 10
9b. Apothecial disc pale yellow to orange..... 11

10a. Apothecial margin smooth; prothallus absent; ascospores 6–9 × 2–3 μm..... ***C. luteocitrinum***
10b. Apothecial margin denticulate; prothallus white; ascospores 7–10 × 2.5–3.5 μm..... ***C. subzonatum***

11a. Ascospores 12–20 μm long ..... ***C. pyrophthalmum***
11b. Ascospores 6–12 μm long 12

12a. Ascospores 2.5–4 μm wide 13
12b. Ascospores 1.8–2.5 μm wide 15

13a. Apothecial margin uneven-denticulate; apothecia up to 1.5 mm broad. ..... ***C. strigosum***
13b. Apothecial margin smooth; apothecia up to 0.8 mm broad..... 14

14a. Apothecial disc wax-colored to pale orange; thallus smooth; prothallus white..... ***C. zonatum***
14b. Apothecial disc pale yellow; thallus verruculose; prothallus absent..... ***C. subdilutum***

15a. Apothecial disc pale yellow-brown; margin denticulate ..... ***C. subdentatum***
15b. Apothecial disc yellow to orange-yellow; margin smooth..... 16

16a. Ascospores 8–12 μm long ..... ***C. nepalense***
16b. Ascospores 6–9 μm long 17

17a. Apothecial disc yellow-orange; conidia 2 × 1.2 µm..... ..... ***C. subfallaciosum***

17b. Apothecial disc pale to bright yellow; conidia 2.5–3.5 × 1.7–2 µm ....***C. geralense***

Coenogonium barbatellum Kalb

Specimen examined. SERGIPE: Santa Luzia, Private property, 11° 19' S, 37° 27' W, Mata Atlântica (closed forest), *Cáceres & Lücking 00-0832* (F, URM).

Coenogonium confervoides Nyl. (FIG. 9D)

Specimen examined. ALAGOAS: Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (closed forest), 50 m, *Cáceres 2002* (B, F, URM).

Coenogonium disjunctum Nyl. (FIG. 9E)

Specimen examined. PERNAMBUCO: Caruaru, Brejo dos Cavalos, 8° 20' S, 35° 58' W, Brejo de Altitude (high altitude rainforest), 800–900 m, *Cáceres & Lücking 00-0670* (B-600124246, F).

Coenogonium geralense (P. Henn) Lücking

Specimens examined. ALAGOAS: Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (closed forest), 50 m, *Cáceres 2074* (URM). PERNAMBUCO: Bonito, Parque Municipal de Bonito, 8° 28' S, 35°43' W, Brejo de Altitude (high altitude rainforest), 800 m, *Cáceres & Lücking 00-0272* (B-600124249). Caruaru, Brejo dos Cavalos, 8° 20' S, 35° 58' W, Brejo de Altitude (high altitude rainforest), 800–900 m, *Cáceres & Lücking 00-0668b* (F).

Coenogonium interplexum Nyl.

Specimens examined. ALAGOAS: Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (forest along main trail), 50 m, *Cáceres A46-435c* (URM). PERNAMBUCO: Bonito, Parque Municipal de Bonito, 8° 28' S, 35°43' W, Brejo de Altitude (high altitude rainforest), 800 m, *Cáceres & Lücking 00-0266* (F).

Coenogonium isidiosum (Breuss) Rivas Plata, Lücking, Umaña & Chaves (FIG. 9F)

Specimen examined. SERGIPE: Ribeira, Mata Atlântica, *Cáceres 2047* (B, F, URM).

Coenogonium leprieurii (Mont.) Nyl.

Specimens examined. ALAGOAS: Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (closed forest), 50 m, *Cáceres &*

Lücking 01-0112 (B-600124255). PERNAMBUCO: Caruaru, Brejo dos Cavalos, 8° 20' S, 35° 58' W, Brejo de Altitude (high altitude rainforest), 800–900 m, *Cáceres & Lücking 00-0548* (B-600124250, F), *00-0900* (B-600124251, F, URM). SERGIPE: Ribeira, Mata Atlântica, *Cáceres 2066* (F, URM).

Coenogonium linkii Ehrenb.

Specimens examined. ALAGOAS: Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (forest along main trail), 50 m, *Cáceres A13-121c* (F), *A41-313a* (F). PERNAMBUCO: Bonito, Parque Municipal de Bonito, 8° 28' S, 35°43' W, Brejo de Altitude (high altitude rainforest), 800 m, *Cáceres & Lücking 00-0267* (B-600124248). Igarassu, Refúgio Ecológico Charles Darwin, 7° 50' S, 34° 54' W, Mata Atlântica (closed forest), 20 m, *Cáceres & Lücking 00-0695* (B, F, URM). SERGIPE: Santa Luzia, Private property, 11° 19' S, 37° 27' W, Mata Atlântica (closed forest), *Cáceres & Lücking 00-0837* (B, F, URM), *s.n.* (F).

Coenogonium luteocitrinum Rivas Plata, Lücking & Umaña

Specimens examined. ALAGOAS: Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (forest along main trail), 50 m, *Cáceres A24-209* (URM). SERGIPE: Santa Luzia, Private property, 11° 19' S, 37° 27' W, Mata Atlântica (closed forest), *Cáceres & Lücking 00-0848a* (F).

Coenogonium moniliforme Tuck. (FIG. 9G)

Specimen examined. SERGIPE: Itabi, Private property, 10° 06' S, 37° 54' W, Caatinga (thornbush), 100 m, *Cáceres 2185* (B, F).

Coenogonium nepalense (G. Thor & Vězda) Lücking, Aptroot & Sipman

ALAGOAS: Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (forest along main trail), 50 m, *Cáceres A41-321c* (F).

Coenogonium pyrophthalmum (Mont.) Lücking, Aptroot & Sipman

Specimens examined. PERNAMBUCO: Caruaru, Brejo dos Cavalos, 8° 20' S, 35° 58' W, Brejo de Altitude (high altitude rainforest), 800–900 m, *Cáceres & Lücking 00-0575* (B, F), *00-0663* (B, F), *00-0667* (URM), *00-0668a* (F), *00-0669* (F). SERGIPE: Santa Luzia, Private property, 11° 19' S, 37° 27' W, Mata Atlântica (closed forest), *Cáceres & Lücking 00-0848b* (F).

Coenogonium strigosum Rivas Plata, Lücking & Chaves

Specimens examined. ALAGOAS: Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (closed forest), 50 m, *Cáceres & Lücking 01-0032* (B-600124247), *01-0093* (F, URM), *Cáceres 2010* (F), *2012* (F), *2018* (F), *2020* (URM). Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (forest along main trail), 50 m, *Cáceres A28-240a* (F). PERNAMBUCO: Bonito, Parque Municipal de Bonito, 8° 28' S, 35°43' W, Brejo de

Altitude (high altitude rainforest), 800 m, *Cáceres & Lücking 00-0273* (F), *00-0274* (URM), *00-0275* (URM). Cabo de Santo Agostinho, Reserva Ecológica de Gurjaú, 8° 19' S, 35° 04' W, Mata Atlântica (closed forest), 30 m, *Cáceres & Lücking 00-0187* (B, F). Caruaru, Brejo dos Cavalos, 8° 20' S, 35° 58' W, Brejo de Altitude (high altitude rainforest), 800–900 m, *Cáceres & Lücking 00-0664b* (F). São Lourenço da Mata, Estação Ecológica de Tapacurá, 8° 02' S, 35° 09' W, Agreste (open dry forest), 100 m, *Cáceres & Lücking 98-0509* (F). SERGIPE: Ribeira, Mata Atlântica, *Cáceres 2027* (F), *2056* (B, F).

Coenogonium subdentatum (Vězda & G. Thor) Rivas Plata, Lücking, Umaña & Chaves (FIG. 9H)

Specimens examined. ALAGOAS: Barra de São Miguel, Reserva Particular do Patrimônio Natural (RPPN) Rosa do Sol, 09° 51' S, 35° 53' W, Mata Atlântica (closed forest), 50 m, *Cáceres 01-0152* (URM), *01-0153* (B, F). Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (forest along main trail), 50 m, *Cáceres A01-001* (B, F), *A01-009a* (URM). Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (forest along main trail), 50 m, *Cáceres A01-009a* (F). PERNAMBUCO: Cabo de Santo Agostinho, Reserva Ecológica de Gurjaú, 8° 19' S, 35° 04' W, Mata Atlântica (closed forest), 30 m, *Cáceres & Lücking 00-0186* (B, F), *00-0224* (F). Igarassu, Refúgio Ecológico Charles Darwin, 7° 50' S, 34° 54' W, Mata Atlântica (closed forest), 20 m, *Cáceres & Lücking 00-0414* (URM).

Coenogonium subdilutum (Malme) Lücking, Aptroot & Sipman

Specimen examined. ALAGOAS: Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (forest along main trail), 50 m, *Cáceres A33-256* (F).

Coenogonium subfallaciosum (Vězda & Farkas) Lücking, Aptroot & Sipman

Specimens examined. PERNAMBUCO: Bonito, Parque Municipal de Bonito, 8° 28' S, 35°43' W, Brejo de Altitude (high altitude rainforest), 800 m, *Cáceres & Lücking 00-0276* (B, F). Recife, Barragem, Mata Atlântica, *Cáceres & Lücking 98-s.n.* (F).

Coenogonium subzonatum (Lücking) Lücking

Specimens examined. ALAGOAS: Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (forest along main trail), 50 m, *Cáceres A09-cortex* (F). PERNAMBUCO: Caruaru, Brejo dos Cavalos, 8° 20' S, 35° 58' W, Brejo de Altitude (high altitude rainforest), 800–900 m, *Cáceres & Lücking 00-0666* (B-600124252, F, URM).

Coenogonium zonatum (Müll. Arg.) Kalb & Lücking

Specimens examined. PERNAMBUCO: Recife, Dois Irmãos, Mata Atlântica (closed forest), *Cáceres & Lücking 99-0501* (B, F), *99-0502* (URM).

Coniocarpon DC. (Arthoniaceae)

Notes. Coniocarpon is currently treated as a synonym of *Arthonia*, but recent studies suggest that this name can be used for species of *Arthonia* s.lat. with small, prominent ascomata producing anthraquinones, typified by the common and widespread *C. cinnabarinum* (GRUBE *et al.* 1995; GRUBE & MATZER 1997). The name *Coniocarpon* is here used to support the notion that this group of species is generically different from *Arthonia*, but a thorough revision of the latter is required to clarify its correct circumscription.

Key to species of *Coniocarpon*

1a. Ascomata strongly elongate and branched ..... ***C.*** spec.
1b. Ascomata short, usually unbranched 2

2a. Ascomata yellow-grey; ascospores 1-septate ..... ***C.*** aff. ***flavocinnabarinum***
2b. Ascomata cinnabar-red; ascospores 3–5-septate ..... ***C. cinnabarinum***

Coniocarpon cinnabarinum DC. (FIG. 10A)

Specimens examined. ALAGOAS: Barra de São Miguel, Reserva Particular do Patrimônio Natural (RPPN) Rosa do Sol, 09° 51' S, 35° 53' W, Mata Atlântica (closed forest), 50 m, *Cáceres 01-0127* (URM). Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (closed forest), 50 m, *Cáceres & Lücking 01-0521* (B, F), *Cáceres 2001* (URM), *2054* (F, URM). Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (forest along main trail), 50 m, *Cáceres A36-cortex* (F). PERNAMBUCO: Caruaru, Instituto Pernambucano de Pesquisas Agropecuárias (IPA), 8° 17' S, 35° 58' W, Caatinga (open thornbush), 500–600 m, *Cáceres & Lücking 00-0012b* (F), *00-0023* (F), *00-0024* (B-600124268, F, URM), *00-0025* (B-600124267, F, URM), *00-0048* (URM), *00-0054* (F), *00-0080* (F). SERGIPE: Itabi, Private property, 10° 06' S, 37° 54' W, Caatinga (thornbush), 100 m, *Cáceres 2165* (F), *2195* (F).

Coniocarpon aff. ***flavocinnabarinum***

Specimens examined. PERNAMBUCO: Caruaru, Brejo dos Cavalos, 8° 20' S, 35° 58' W, secondary vegetation (fence posts), 800–900 m, *Cáceres & Lücking s.n.* (F).

Coniocarpon spec.

Specimen examined. PERNAMBUCO: Caruaru, Instituto Pernambucano de Pesquisas Agropecuárias (IPA), 8° 17' S, 35° 58' W, Caatinga (open thornbush), 500–600 m, *Cáceres & Lücking 00-0026* (F).

Cratiria Marbach (Physciaceae)

Notes. This is another segregate of *Buellia* s.lat. established by MARBACH (2000). The genus is relatively variable and difficult to separate clearly from *Baculifera* and *Hafellia*, but most of the species have a rather thick thallus with black prothallus, shortly bacillar conidia, and a three-layered excipulum with a pale inner part. The common species *C. lauricassiae* and *C. obscurior* are relatively robust and thus well-recognized even in the field, although microscopical examination is necessary to separate them.

Key to species of *Cratiria*

1a. Ascospores 3-septate ..... ***C. lauricassiae***
1b. Ascospores 1-septate ..... ***C. obscurior***

Cratiria lauricassiae (Fée) Marbach (FIG. 10B)

Specimens examined. PERNAMBUCO: Caruaru, Instituto Pernambucano de Pesquisas Agropecuárias (IPA), 8° 17' S, 35° 58' W, Caatinga (open thornbush), 500–600 m, *Cáceres & Lücking 00-0084a* (B-600124009, F). Recife, Universidade Federal de Pernambuco (UFPE), secondary vegetation on campus, *Cáceres & Lücking 98-s.n.* (F, URM).

Cratiria obscurior (Stirton) Marbach & Kalb (FIG. 10C)

Specimens examined. PERNAMBUCO: Caruaru, Instituto Pernambucano de Pesquisas Agropecuárias (IPA), 8° 17' S, 35° 58' W, Caatinga (open thornbush), 500–600 m, *Cáceres & Lücking 00-0075* (B-600124012, F, URM).

Cresponea Egea & Torrente (Roccellaceae)

Notes. This genus is similar to *Bactrospora* at first glance but differs in its ascospore type (same as *Opegrapha*) and its green rather than white thallus, which coincides with its ecology being a genus commonly found in the rainforest understory (EGEA & TORRENTE 1993). Most species have black apothecia with a yellow pruina on the disc and are hence easily recognized at genus level, while microscopic examination of ascospores is required to identify the species.

Key to species of *Cresponea*

1a. Ascospores 3–5-septate, 15–25 × 4-4.5 µm ..... ***C. flava***
1b. Ascospores 7–19-septate, 25–90 × 5–7 µm..... 2

2a. Ascospores 7(–9)-septate, 25–40 µm long ..... ***C. proximata***
2b. Ascospores 9–19-septate, 35–90 µm long..... 3

3a. Ascospores 9–13-septate, 35–65 µm long..... ***C. leprieurii***

3b. Ascospores 13–19-septate, 65–90 µm long..... ***C. melanocheloides***

Cresponea flava (Vain.) Egea & Torrente

Specimen examined. RIO GRANDE DO NORTE: Baía Formosa, Reserva Particular do Patrimônio Natural (RPPN) Mata Estrela Senador Antônio Farias, 06° 22' S, 35° 01' W, Mata Atlântica (closed forest), 0 m, *Cáceres 01-0185* (F).

Cresponea leprieurii (Mont.) Egea & Torrente

Specimen examined. PERNAMBUCO: Bonito, Parque Municipal de Bonito, 8° 28' S, 35°43' W, Brejo de Altitude (high altitude rainforest), 800 m, *Cáceres & Lücking 00-0348* (B-600124262, F, URM).

Cresponea melanocheiloides (Vain.) Egea & Torrente (FIG. 10D)

Specimens examined. ALAGOAS: Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (closed forest), 50 m, *Cáceres & Lücking 01-0027* (B-600124263), *01-0162* (F). RIO GRANDE DO NORTE: Baía Formosa, Reserva Particular do Patrimônio Natural (RPPN) Mata Estrela Senador Antônio Farias, 06° 22' S, 35° 01' W, Mata Atlântica (closed forest), 0 m, *Cáceres 01-0179* (URM), *01-0189a* (B-600124177, F)

Cresponea proximata (Nyl.) Egea & Torrente

Specimens examined. RIO GRANDE DO NORTE: Baía Formosa, Reserva Particular do Patrimônio Natural (RPPN) Mata Estrela Senador Antônio Farias, 06° 22' S, 35° 01' W, Mata Atlântica (closed forest), 0 m, *Cáceres s.n.* (F). SERGIPE: Santa Luzia, Private property, 11° 19' S, 37° 27' W, Mata Atlântica (closed forest), *Cáceres & Lücking 00-0838b* (F).

Crocynia (Ach.) A. Massal. (Ramalinaceae)

Notes. This genus includes leprarioid lichens with a byssoid rather than leprose thallus structure. There are two common tropical species which can usually be identified with some experience even in the sterile condition.

Key to species of *Crocynia*

1a. Thallus appearing lobate; prothallus black..... ***C. pyxinoides***
1b. Thallus irregular; prothallus absent.....***C. gossypina***

Crocynia gossypina (Sw.) A. Massal.

Specimens examined. ALAGOAS: Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (forest along main trail), 50 m, *Cáceres A34-263c* (B), *A34-264a* (F).

Crocynia pyxinoides Nyl.

Specimen examined. ALAGOAS: Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (forest along main trail), 50 m, *Cáceres A18-165b* (B).

Cryptolechia A. Massal. (Gyalectaceae)

Notes. Cryptolechia is somewhat similar to *Gyalecta* and crustose species of *Coenogonium* in appearance but is distinguished by its more brownish instead of yellow-orange colors, from *Gyalecta* by its 8–16-spored asci and from *Coenogonium* by its more than 1-septate ascospores, 8–16-spored asci and persistently I+ blue hymenium (HAWKSWORTH & DIBBEN 1982).

Cryptolechia nana (Tucker) D. Hawksw. & Dibben (FIG. 10E)

Specimen examined. ALAGOAS: Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (forest along main trail), 50 m, *Cáceres A33-259* (B, F).

Cryptothecia Stirt. (Arthoniaceae)

Notes. Cryptothecia is one of the most abundant and at the same time one of the least well-known lichen genera in tropical lowland forests. The white 'tree bark' typical of many fast-growing rainforest trees is in fact caused by lichens, many of which are sterile *Cryptothecia* species. The lack of distinct ascomata or the difficulty to detect fertile thalli in the field is the cause that this genus is strongly undercollected, but studies based on quantitative collections of sterile material as part of this dissertation indicate a high diversity of species distinguished by chemical characters (CÁCERES *et al.* 2007c). The genus is best studied in the Indian subcontinent (AWASTHI & AGARWAL 1969; MAKHIJA & PATWARDHAN 1985, 1987, 1994), but the first modern circumscription was provided recently by THOR (1997), based on collections from Australia. Traditionally, *Cryptothecia* included species with uncolored, undefined ascomata or asci scattered in the thallus, and muriform ascospores, but also several sterile taxa with similar thallus morphology. In a modern sense, *Cryptothecia* seems to be defined by its thin, effuse thallus structure with byssoid prothallus and unorganized to well-organized ascomata lacking hymenial jelly. Species with a thicker, almost byssoid thallus and ascomata with well-developed walls are now separated in the genus *Herpothallon* (see below). Apart from the five species of *Cryptothecia* listed below, six further, unidentified taxa were found in the present material. All are sterile but distinctive through their micromorphology and chemical profile; they will be treated in a forthcoming paper.

Key to species of *Cryptothecia*

1a. Thallus with discrete, maculate soralia ..... ***C. punctosorediata***
1b. Thallus lacking soralia..... 2

2a. Thallus C+ red (gyrophoric acid); asci 1-spored; white prothallus well-developed, giving the thallus a zoned appearance ..... ***C. striata***
2b. Thallus C–; asci 8-spored; prothallus indistinct 3

3a. Ascomata well-organized, forming distinct, well-delimited white spots on the otherwise green thallus; no substances present .... ***C. subcandida***
3b. Ascomata unorganized, the individual asci instead scattered over the thallus surface, often hard to see; perlatolic acid and unknown substances present 4

4a. Individual asci arranged in lines, often radiating from the center ..... ***C. effusa***
4b. Individual asci arranged in irregular patches, not forming lines ..... ***C.*** aff. ***effusa***

Cryptothecia effusa (Müll. Arg.) R. Sant.

Specimens examined. ALAGOAS: Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (forest along main trail), 50 m, *Cáceres A05-037a* (B), *A41-314* (F), *A42-314* (F), *A44-348a* (F), *A47-447* (F). PERNAMBUCO: Caruaru, Instituto Pernambucano de Pesquisas Agropecuárias (IPA), 8° 17' S, 35° 58' W, Caatinga (open thornbush), 500–600 m, *Cáceres & Lücking 00-0019* (F). Igarassu, Refúgio Ecológico Charles Darwin, 7° 50' S, 34° 54' W, Mata Atlântica (closed forest), 20 m, *Cáceres & Lücking 00-0410* (URM), *00-0691* (B, F, URM).

Cryptothecia aff. ***effusa*** (Müll. Arg.) R. Sant.

Specimen examined. PERNAMBUCO: Igarassu, Refúgio Ecológico Charles Darwin, 7° 50' S, 34° 54' W, Mata Atlântica (closed forest), 20 m, *Cáceres & Lücking 00-0483* (F).

Cryptothecia punctosorediata Sparrius & Saipunkaew (FIG. 10F)

Notes. The material agrees with the recently described *Cryptothecia punctosorediata* from Thailand (SPARRIUS & SAIPUNKAEW 2005) in the discrete, maculate soralia. However, while in the material from Thailand, only the soralia are C+ red, in the present material the entire thallus contains gyrophoric acid and reacts C+ red. Ascomata have not been found.

Specimens examined. ALAGOAS: Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (closed forest), 50 m, *Cáceres*

2072 (F), *A46-426b* (F). PERNAMBUCO: Igarassu, Refúgio Ecológico Charles Darwin, 7° 50' S, 34° 54' W, Mata Atlântica (closed forest), 20 m, *Cáceres & Lücking 00-0396* (B, F).

Cryptothecia striata G. Thor (FIG. 10G)

Specimens examined. ALAGOAS: Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (closed forest), 50 m, *Cáceres & Lücking 01-0504* (F), *Cáceres 2072* (URM). Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (forest along main trail), 50 m, *Cáceres A01-016a* (URM), *A04-016* (F), *A04-033* (URM), *A25-213a* (F), *A27-230* (B), *A28-230* (F), *A30-246* (F), *A31-246* (URM), *A33-252* (URM), *A34-262a* (F), *A34-263b* (B), *A36-277a* (F), *A44-346* (URM), *A45-361* (B), *A45-367a* (F). PERNAMBUCO: Cabo de Santo Agostinho, Reserva Ecológica de Gurjaú, 8° 19' S, 35° 04' W, Mata Atlântica (closed forest), 30 m, *Cáceres & Lücking 00-0146* (URM). Igarassu, Refúgio Ecológico Charles Darwin, 7° 50' S, 34° 54' W, Mata Atlântica (closed forest), 20 m, *Cáceres & Lücking 00-0482* (B, F).

Cryptothecia subcandida Cáceres & Lücking **spec. nova** (FIG. 10H)

Cryptothecia candida ascomata et ascosporis minoribus et acidis lichenum nullis differt. — Typus. PERNAMBUCO: Igarassu, Refúgio Ecológico Charles Darwin, 7° 50' S, 34° 54' W, Mata Atlântica (closed forest), 20 m, *Cáceres & Lücking 00-0409* (URM, holotypus). — Paratypi. ALAGOAS: Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (closed forest), 50 m, *Cáceres & Lücking 01-0045* (F), *01-0047* (B). Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (forest along main trail), 50 m, *Cáceres A34-264* (F), *A41-317* (F), *A42-317* (F). PERNAMBUCO: Igarassu, Refúgio Ecológico Charles Darwin, 7° 50' S, 34° 54' W, Mata Atlântica (closed forest), 20 m, *Cáceres & Lücking 00-0399* (URM), *00-0402* (B, F, URM), *00-0408* (B, F), *00-0693* (F).

Description. Thallus corticolous, crustose, continuous, smooth to minutely farinose-byssoid, 10–20 mm across and 15–25 μm thick, ecorticate, green, matt, in section with scattered, colorless, hydrophobic crystals dissolving in K. Photobiont *Trentepohlia*; cells rounded to oblong, 8–12 × 4–6 μm, in irregular plates or short threads leaving interspaces. Ascomata erumpent to sessile, distinctly raised over thallus level, rounded to slightly irregular, 0.4–0.7 mm diam. and 80–100 μm high, white. Hypothecium indistinct. Ascigerous layer 60–80 μm high, colorless to yellow-grey due to sparse inspersion of interascal hyphae with small crystals (dissolving in K), I+ blue, KI+ blue then green, with scattered algal cells above. Asci obovate to globose, 50–70 × 40–60 μm, I–, KI–. Ascospores 8 per ascus, ellipsoid to oval, muriform, with very slight constrictions at septa, 30–50 × 12–22 μm, 2.5–3.5 times as long as broad. Pycnidia not observed. Chemistry: no substances detected by TLC.

Notes. This new species belongs in the *Cryptothecia candida* complex and is morphologically most similar to the neotropical *C. filicina*; the latter,

however, has much larger ascomata and larger ascospores and also differs in chemistry (LÜCKING *et al.* 2006). The comparatively small ascomata of *C. subcandida* at first glance resemble soralia of an otherwise sterile lichen, but asci are quite abundantly found once the 'soralia' are sectioned.

Cryptothelium A. Massal. (Trypetheliaceae)

Notes. Cryptothelium is another artificial genus in the Trypetheliaceae, with the same type of fused perithecia as *Astrothelium* (see above) but differing in its muriform ascospores (HARRIS 1986; MAKHIJA & PATWARDHAN 1989; APTROOT 1991). The species found here is the most common in the genus.

Cryptothelium sepultum (Mont.) A. Massal. (FIG. 11A)

Specimen examined. SERGIPE: Areia Branca, Reserva Ecológica Serra de Itabaiana, 10° 45' S, 37° 20' W, Mata Atlântica (closed forest), 500 m, *Cáceres 2080* (B, F).

Dichosporidium Pat. (Roccellaceae)

Notes. Dichosporidium is one of several genera in the Arthoniales with byssoid thallus, including also *Ancistrospora*, *Herpothallon*, *Sagenidium*, *Sagenidiopsis*, *Streimannia*, *Tania*, and others (THOR 1990; EGEA *et al.* 1995; GRUBE 1998). *Dichosporidium* can be distinguished from the other genera by its perithecioid ascomata aggregated in stromata, the same way as in *Chiodecton*, and by its hooked to biclavate ascospores (THOR 1990). However, ascomata are often absent and instead, felty isidia are produced which are very similar to those found in the genus *Herpothallon*. *Dichosporidium* can be distinguished from the latter in having an entirely byssoid thallus, while in *Herpothallon*, only the prothallus is byssoid and the thallus is rather compact instead.

Key to species of *Dichosporidium*

1a. Isidia fuzzy ..... ***D. lanuginosum***
1b. Isidia cylindrical ..... ***D. nigrocinctum***

Dichosporidium lanuginosum Aptroot & Lücking (FIG. 11B)

Specimens examined. ALAGOAS: Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (closed forest), 50 m, *Cáceres & Lücking 01-0579* (F). PERNAMBUCO: Bonito, Parque Municipal de Bonito, 8° 28' S, 35°43' W, Brejo de Altitude (high altitude rainforest), 800 m, *Cáceres & Lücking 00-0282* (B, F).

Dichosporidium nigrocinctum (Ehrenb.) G. Thor (FIG. 11C)

Specimens examined. ALAGOAS: Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (closed forest), 50 m, *Cáceres & Lücking 01-0091* (URM), *01-0579* (F), *01-0582* (F). Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (forest along main trail), 50 m, *Cáceres A08-069* (URM), *A12-114a* (URM), *A12-119b* (F), *A13-121b* (F), *A13-128* (F), *A18-171* (F), *A21-184b* (B), *A21-185a* (B, F), *A21-186* (URM), *A27-234a* (F), *A27-235* (B), *A28-235* (F), *A30-244* (F), *A31-244* (B, F), *A31-246a* (F), *A34-263a* (B), *A34-264b* (F), *A35-274b* (F), *A36-276* (URM), *A36-280d* (URM), *A37-285c* (URM), *A37-287b* (F). PERNAMBUCO: Cabo de Santo Agostinho, Reserva Ecológica de Gurjaú, 8° 19' S, 35° 04' W, Mata Atlântica (closed forest), 30 m, *Cáceres & Lücking 00-0137* (F, URM), *00-0138* (B, F), *00-0139* (B, F, URM).

Dictyonema C. Agardh ex Kunth (Atheliaceae)

Notes. Dictyonema is one of several basidiolichen genera and the one with the highest number of species and the one most abundantly found in the tropics (PARMASTO 1978; CHAVES *et al.* 2004). In its current definition, it includes both foliose and filamentous taxa, and the importance of growth form for species delimitation is unclear. The genus is most typical of very humid montane rainforests, and only one taxon was found in the present material.

Dictyonema phyllogenum f. nitidum Lücking (FIG. 11D)

Specimen examined. PERNAMBUCO: Caruaru, Brejo dos Cavalos, 8° 20' S, 35° 58' W, Brejo de Altitude (high altitude rainforest), 800–900 m, *Cáceres & Lücking 00-0646* (B, F).

Diorygma Eschw. (Graphidaceae)

Notes. Diorygma is one of a number of genera now accepted in Graphidaceae in the light of a more natural genus concept (STAIGER 2002; ARCHER 2005). The genus was recently monographed (KALB *et al.* 2004), and it was shown that two further generic names, *Glaucinaria* and *Solenographa*, previously thought to represent autonomous genera, are synonymous with *Diorygma*. Species of *Diorygma* are typical of tropical rainforests and are usually characterized by their ecorticate thalli, more or less exposed, pruinose apothecial disc, mostly large, muriform ascospores, and rich secondary chemistry.

Key to species of *Diorygma*

1a. Lirellae sessile; thallus UV+ yellow; lichexanthone and stictic acid ..... ***D. alagoense***

1b. Lirellae immersed, adnate or erumpent; thallus UV–; lichexanthone absent 2

2a. Ascospores 2–8 per ascus, less than 100 µm long; hypostictic and hypoconstictic acids 3
2b. Ascospores 1 per ascus, 95-230 µm long; stictic, norstictic and/or protocetraric acids 4

3a. Ascospores 40–65 × 10–18 µm, 4–8 per ascus ..... ***D. poitaei***
3b. Ascospores 45–100 × 15-30 µm, 2–8 per ascus ..... ***D. sipmanii***

4a. Protocetraric acid only (thallus K–) ..... ***D. africanum***
4b. Stictic, norstictic, salazinic and/or protocetraric acids (thallus K+ yellow to red) 5

4a. Lirellae immersed, elongate; ascospores 95–170 × 30–45 µm; stictic and norstictic acids ..... ***D. hieroglyphicum***
4b. Lirellae adnate, short; ascospores 110–230 × 35–80 µm; norstictic, protocetraric and salazinic acids ..... ***D. reniforme***

Diorygma africanum Kalb, Staiger & Elix

Specimen examined. PERNAMBUCO: Caruaru, Brejo dos Cavalos, 8° 20' S, 35° 58' W, Brejo de Altitude (high altitude rainforest), 800–900 m, *Cáceres & Lücking 00-0600* (B, F).

Diorygma alagoense Cáceres & Lücking **spec. nova** (FIG. 11E)

Diorygma confluente apotheciis sessilibus et ascosporis minoribus differt. — Typus. ALAGOAS: Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (closed forest), 50 m, *Cáceres & Lücking 01-0008* (URM, holotype; B, F, isotypes). — Paratypi. Same locality, *Cáceres & Lücking 01-0015* (F, URM), *01-0016* (B, F), *01-0017* (F).

Description. Thallus crustose, corticolous, continuous, smooth to minutely farinose, up to 50 mm across and 50–100 µm thick, ecorticate, pale yellow-grey, UV+ bright yellow. Photobiont *Trentepohlia*; cells angular-rounded, 5–10 × 4–7 µm. Apothecia erumpent to finally sessile, rounded to elongate, 0.5–1.5 × 0.4–0.7 mm and 250–350 µm high; always 4–7 apothecia in irregular to stellate clusters up to 4 × 3 mm across; disc concave to plane, with thick and persistent, white to cream-colored pruina, UV–; proper margin distinct, with white to cream-colored pruina, UV–, laterally covered by bulging thalline margin which is UV+ bright yellow; often with split between proper and thalline margin. Excipulum not carbonized, 20–30 µm broad, orange-brown; lateral thalline margin 100–150 µm broad, its structure nubilous by grey crystals that dissolve in KOH. Hypothecium 30–60 µm high, orange-brown. Epithecium well-developed, composed of strongly branched and anastomosing paraphysal tips, 30–50 µm high, dark

grey due to strong incrustation with small crystals which dissolve in KOH. Hymenium 130–160 µm high, colorless. Paraphyses mostly unbranched except at the tips, with thin lumina. Asci 120–150 × 25–30 µm. Ascospores 6–8 per ascus, oblong-ellipsoid, muriform, 40–60 × 10–14 µm, 3.5–4.5 times as long as broad, colorless, I+ violet-blue. Pycnidia not observed. Chemistry: lichexanthone (thallus only), stictic acid.

Notes. Diorygma alagoense is a well-defined new species in the genus, characterized especially by its aggregate, often rounded apothecia. The chemistry suggests a close relationship with *D. confluens* and *D. epiglaucum*, but the latter two have 1–2-spored asci with much larger ascospores and a black hypothallus that frequently flakes off the substrate. Also, their apothecia are more distinctly lirelliform and not aggregate. All other species of the genus differ clearly from *D. alagoense* in both their chemistry and apothecial morphology.

Diorygma hieroglyphicum (Pers.) Staiger & Kalb (FIG. 11F)

Specimen examined. SERGIPE: Itabi, Private property, 10° 06' S, 37° 54' W, Caatinga (thornbush), 100 m, *Cáceres 2157* (B, F, URM).

Diorygma poitaei (Fée) Kalb, Staiger & Elix (FIG. 11G)

Specimens examined. ALAGOAS: Barra de São Miguel, Reserva Particular do Patrimônio Natural (RPPN) Rosa do Sol, 09° 51' S, 35° 53' W, Mata Atlântica (closed forest), 50 m, *Cáceres 01-0133* (B, F, URM). Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (closed forest), 50 m, *Cáceres & Lücking 01-0120* (F, URM), *01-0518b* (F), *01-0522* (F), *01-0570* (F), *Cáceres 2009* (F), *2016* (F), *s.n.* (URM), *s.n.* (URM). Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (forest along main trail), 50 m, *Cáceres A05-036* (B, F), *A05-037b* (B), *A05-038* (URM), *A05-041a* (F), *A07-053* (F, URM), *A12-114b* (URM), *A12-115* (F), *A12-119c* (F), *A12-120b* (F), *A14-130* (URM), *A17-155* (B), *A17-159a* (URM), *A25-210* (URM), *A26-220* (URM), *A27-232* (F), *A28-232* (F), *A29-242a* (B), *A34-266* (B), *A35-270a* (F), *A38-289a* (F), *A38-290* (B), *A38-291a* (F), *A39-300* (B, F), *A40-302* (URM), *A41-325* (URM), *A42-325* (F), *A42-327a* (URM), *A42-332* (URM), *A44-344* (URM), *A46-418* (URM), *A46-432* (URM), *A47-440* (B). PERNAMBUCO: Bonito, Parque Municipal de Bonito, 8° 28' S, 35°43' W, Brejo de Altitude (high altitude rainforest), 800 m, *Cáceres & Lücking 00-0362* (B-600124037). Cabo de Santo Agostinho, Reserva Ecológica de Gurjaú, 8° 19' S, 35° 04' W, Mata Atlântica (closed forest), 30 m, *Cáceres & Lücking 00-0161* (URM), *00-0162* (F), *00-0163* (B-600124034), *00-0164* (URM), *00-0165* (URM), *00-0166* (F), *00-0167* (B-600124035, F, URM), *00-0168* (B-600124036), *00-0241* (F), *00-0244* (URM), *00-0247* (F). Caruaru, Brejo dos Cavalos, 8° 20' S, 35° 58' W, Brejo de Altitude (high altitude rainforest), 800–900 m, *M. Cáceres & R. Lücking00-0643* (F), *00-0647* (B-600124038). Igarassu, Refúgio Ecológico Charles Darwin, 7° 50' S, 34° 54' W, Mata Atlântica (closed forest), 20 m, *Cáceres & Lücking 00-0517* (F), *00-0518* (URM), *00-0519* (F), *00-0520* (F, URM). SERGIPE: Santa Luzia, Private property, 11° 19' S, 37° 27' W, Mata Atlântica (closed forest), *Cáceres & Lücking 00-0854* (F). Ribeira, Mata Atlântica, *Cáceres 2026* (F), *2029* (F).

Diorygma reniforme (Fée) Kalb, Staiger & Elix (FIG. 11H)

Specimens examined. PERNAMBUCO: Bonito, Parque Municipal de Bonito, 8° 28' S, 35°43' W, Brejo de Altitude (high altitude rainforest), 800 m, *Cáceres & Lücking 00-0361* (URM), *00-0382* (B-600124013), *00-0383* (B-600124014), *00-0384* (URM), *00-0385* (F), *00-0386* (URM), *00-0387* (B-600124015, F), *00-0388* (B-600124016, F, URM). Caruaru, Brejo dos Cavalos, 8° 20' S, 35° 58' W, Brejo de Altitude (high altitude rainforest), 800–900 m, *Cáceres & Lücking 00-0645* (F, URM), *00-0648* (B-600124017), *00-0649* (F).

Diorygma sipmanii Kalb, Staiger & Elix

Specimens examined. PERNAMBUCO: Caruaru, Brejo dos Cavalos, 8° 20' S, 35° 58' W, Brejo de Altitude (high altitude rainforest), 800–900 m, *Cáceres & Lücking 00-0637* (F).

Dirinaria (Tuck.) Clem. (Physciaceae)

Notes. Species of *Dirinaria* are characterized by their closely appressed, microfoliose thalli lacking rhizines, in combination with atranorin as cortical substance (thallus K+ yellow) and mostly divaricatic acid in the medulla, giving a UV+ blue-white fluorescense (AWASTHI 1975).

Key to species of *Dirinaria*

1a. Soralia present 2
1b. Soralia absent..... 4

2a. Soralia and medulla cinnabar-red ..... ***D. leopoldii***
2b. Soralia and medulla white 3

3a. Lobes plicate, strongly confluent towards the tips ..... ***D. applanata***
3b. Lobes flat, discrete towards the tips ..... ***D. picta***

4a. Apothecia purplish pruinose..... ***D. purpurascens***
4b. Apothecia non-pruinose..... 5

5a. Medulla with divaricatic acid ..... ***D. confluens***
5b. Medulla with sekikaic acid ..... ***D. confusa***

Dirinaria applanata (Fée) D. D. Awasthi

Specimen examined. ALAGOAS: Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (forest along main trail), 50 m, *Cáceres A04-027* (URM).

Dirinaria confluens (Fr.) D. D. Awashti (FIG. 12A)

Specimen examined. PERNAMBUCO: Garanhuns, secondary Caatinga vegetation, *Cáceres & Lücking 98-0500a* (F).

Dirinaria confusa D. D. Awasthi

Specimen examined. PERNAMBUCO: Recife, Universidade Federal de Pernambuco (UFPE), secondary vegetation on campus, *Cáceres & Lücking 98-s.n.* (B, F, URM).

Dirinaria leopoldii (Stein) D. D. Awasthi (FIG. 12B)

Specimens examined. PERNAMBUCO: Caruaru, Instituto Pernambucano de Pesquisas Agropecuárias (IPA), 8° 17' S, 35° 58' W secondary vegetation (open area in front of main building), 500–600 m, *Cáceres & Lücking 00-0111* (B-600124018), *00-0121b* (B-600124162). Caruaru, Instituto Pernambucano de Pesquisas Agropecuárias (IPA), 8° 17' S, 35° 58' W, Caatinga (open thornbush), 500–600 m, *Cáceres & Lücking 00-0020b* (B-600124271). Sergipe: Gararu, 9° 58' S, 37° 54' W, Caatinga (thornbush), 0–100 m, *Cáceres 2112b* (B), *2151a* (F, URM). Ribeira, Mata Atlântica, *Cáceres 2055* (F, URM), *2059* (F).

Dirinaria picta (Sw.) Schaer. ex Clem. (FIG. 12C)

Specimens examined. ALAGOAS: Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (forest along main trail), 50 m, *Cáceres A01-003* (URM), *A04-029* (F), *A15-136* (B), *A43-337* (F), *A43-338a* (URM). PERNAMBUCO: São Lourenço da Mata, Estação Ecológica de Tapacurá, 8° 02' S, 35° 09' W, Agreste (open dry forest), 100 m, *Cáceres & Lücking 98-0264* (F). Caruaru, Brejo dos Cavalos, 8° 20' S, 35° 58' W, secondary vegetation (fence posts), 800–900 m, *Cáceres & Lücking 00-0803e* (F), *00-0807c* (B-600124157).

Dirinaria purpurascens (Vain.) B. J. Moore (FIG. 12D)

Specimen examined. PERNAMBUCO: Caruaru, Instituto Pernambucano de Pesquisas Agropecuárias (IPA), 8° 17' S, 35° 58' W secondary vegetation (open area in front of main building), 500–600 m, *Cáceres & Lücking 00-0110* (B, F). SERGIPE: Gararu, 9° 58' S, 37° 54' W, Caatinga (thornbush), 0–100 m, *Cáceres 2126* (URM).

Dyplolabia A. Massal. (Graphidaceae)

Notes. Dyplolabia is another recent segregate of the genus *Graphis*, including species with carbonized labia concealing the disc, a white pruina containing lecanoric acid (C+ red), and small, I-negative ascospores (KALB & STAIGER 2001; STAIGER 2002). The C+ red reaction immediately separates the genus from superficially similar taxa in *Carbacanthographis* and *Graphis*. The two known species were both found in the present material.

Key to species of *Dyplolabia*

1a. Ascospores 3-septate .....***D. afzelii***

1b. Ascospores submuriform..... ***D. oryzoides***

Dyplolabia afzelii (Ach.) A. Massal. (FIG. 12E)

Specimens examined. ALAGOAS: Barra de São Miguel, Reserva Particular do Patrimônio Natural (RPPN) Rosa do Sol, 09° 51' S, 35° 53' W, Mata Atlântica (closed forest), 50 m, *Cáceres 01-0131* (URM), *01-0154* (B, F). PERNAMBUCO: Bonito, Parque Municipal de Bonito, 8° 28' S, 35°43' W, Brejo de Altitude (high altitude rainforest), 800 m, *Cáceres & Lücking 00-0372* (B-600124020, F), *00-0374* (URM), *00-0375* (URM). Cabo de Santo Agostinho, Reserva Ecológica de Gurjaú, 8° 19' S, 35° 04' W, Mata Atlântica (closed forest), 30 m, *Cáceres & Lücking 00-0245* (F). Caruaru, Brejo dos Cavalos, 8° 20' S, 35° 58' W, Brejo de Altitude (high altitude rainforest), 800–900 m, *Cáceres & Lücking 00-0653* (B-600124025), *00-0654* (B-600124026), *00-0652* (F), *00-0653* (F). Caruaru, Instituto Pernambucano de Pesquisas Agropecuárias (IPA), 8° 17' S, 35° 58' W secondary vegetation (open area in front of main building), 500–600 m, *Cáceres & Lücking 00-0006* (F). Igarassu, Refúgio Ecológico Charles Darwin, 7° 50' S, 34° 54' W, Mata Atlântica (closed forest), 20 m, *Cáceres & Lücking 00-0512* (URM), *00-0513* (F), *00-0514* (B-600124021, F), *00-0515* (F), *00-0516* (B-600124023, F, URM), *00-0517* (B-600124024). SERGIPE: Areia Branca, Reserva Ecológica Serra de Itabaiana, 10° 45' S, 37° 20' W, Mata Atlântica (closed forest), 500 m, *Cáceres & Lücking 2193* (URM), *2194* (URM). Santa Luzia, Private property, 11° 19' S, 37° 27' W, Mata Atlântica (closed forest), *Cáceres & Lücking 00-0821* (F), *00-0863* (URM), *00-0864* (F, URM), *00-0867* (F), *00-0876* (URM), *00-0877* (F).

Dyplolabia oryzoides (Leight.) Kalb & Staiger (FIG. 12F)

Specimen examined. ALAGOAS: Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (closed forest), 50 m, *Cáceres & Lücking 01-0022a* (B, F, URM).

Echinoplaca Fée (Gomphillaceae)

Notes. Species of *Echinoplaca* are mostly foliicolous, but can also be found on smooth bark, especially on small twigs (KALB & VĚZDA 1988). The genus is recognized by its verruculose thallus, filled with calcium oxalate crystal clusters, and its adnate, spot-like apothecia; the photobiont is chloro-coccoid (LÜCKING *et al.* 2005; LÜCKING 2007). The genus *Arthonia* is superficially similar, but apart from the thallus structure and photobiont, *Echinoplaca* is separated from the latter by its non-amyloid hymenium, annelasceous asci and thin-walled ascospores.

Key to species of *Echinoplaca*

1a. Ascospores 15–27-septate, 2–6 per ascus, 60–100 × 10–18 µm..... ..... ***E. leucotrichoides***

1b. Ascospores muriform, 1–2 per ascus, 15–37 µm broad..... 2

2a. Disc color brown; ascospores 2 per ascus, 50–90 × 15–23 µm .....

.....***E. bispora***

2b. Disc color yellow; ascospores 1 per ascus, 60–70 × 25–37 μm.....
.....***E. caruaruensis***

Echinoplaca bispora Kalb & Vězda (FIG. 12G)

Specimens examined. PERNAMBUCO: Caruaru, Brejo dos Cavalos, 8° 20' S, 35° 58' W, Brejo de Altitude (high altitude rainforest), 800–900 m, *Cáceres & Lücking 00-0603* (B-600124027), *00-0604* (F), *00-0899* (F).

Echinoplaca caruaruensis Cáceres & Lücking **spec. nova** (FIG. 12H)

Echinoplaca simile apotheciis pallidis differt. — Typus. PERNAMBUCO: Caruaru, Brejo dos Cavalos, 8° 20' S, 35° 58' W, Brejo de Altitude (high altitude rainforest), 800–900 m, *Cáceres & Lücking 00-0606* (URM, holotypus).

Description. Thallus crustose, corticolous, continuous, 5–10 mm across and 15–35 μm thick, with cartilaginous, corticiform layer, coarsely and irregularly verrucose due to incrustation with calcium oxalate crystals, pale greenish grey; verrucae 0.1–0.2 mm diam., of same color as thallus. Photobiont *Trebouxia*; cells 5–7 μm diam. Apothecia adnate and spot-like, not or very slightly raised over thallus level, emarginate or margin very indistinct, rounded, 0.3–0.6 mm diam. and 80–100 μm high; disc plane, brown-yellow, slightly translucent. Excipulum composed of branched, radiating hyphae embedded in gelatinous matrix, reduced and spreading over thallus surface, 50–100 μm broad, colorless to pale yellow. Hypothecium 5–10 μm high, colorless to pale yellow-brown. Epithecium indistinct. Hymenium 70–90 μm high, colorless. Paraphyses richly branched and anastomosing, 0.7–1 μm thick. Asci broadly clavate to ovoid, 65–85 × 30–40 μm. Ascospores 1 per ascus, broadly ellipsoid, muriform, with slight constrictions at septa, 60–70 × 25–37 μm, 2–3 times as long as broad. Hyphophores not observed. Chemistry: no substances detected by TLC.

Notes. Echinoplaca caruarensis is similar to a couple of other species in the genus with large, muriform ascospores, such as *E. epiphylla*, *E. melanothrix*, *E. leucomuralis*, *E. vezdana*, *E. bispora*, and *E. similis* (KALB & VĚZDA 1988; LÜCKING 2007). The color of the apothecia is most similar to those found in *E. melanothrix*, *E. leucomuralis*, and *E. vezdana*, but *E. melanothrix* has abundant black hyphophores and much smaller ascospores, while *E. leucomuralis* has short, white hyphophores with black tips and narrower ascospores in numbers of 1–4 per ascus. *Echinoplaca vezdana* is most similar in thallus and apothecial morphology, but its apothecia are much larger and it has much narrower ascospores in numbers of 2–4 per ascus. The chiefly foliicolous *E. epiphylla* differs in its orange-yellow, com-

pletely applanate apothecia and its abundant white sterile thallus setae. Finally, *E. bispora* and *E. similis* have much darker, chocolate brown apothecia and short white hyphophores and more or less white thalli.

Echinoplaca leucotrichoides (Vain.) R. Sant.

Specimens examined. PERNAMBUCO: Bonito, Parque Municipal de Bonito, 8° 28' S, 35°43' W, Brejo de Altitude (high altitude rainforest), 800 m, *Cáceres & Lücking 00-0310* (F), *00-0311* (B-600124091). Caruaru, Brejo dos Cavalos, 8° 20' S, 35° 58' W, Brejo de Altitude (high altitude rainforest), 800–900 m, *Cáceres & Lücking 00-0599a* (F), *00-0601b* (F).

Enterographa Fée (Roccellaceae)

Notes. This genus of chiefly tropical lichens has recently been monographed by SPARRIUS (2004). Among Roccellaceae, *Enterographa* is characterized by its usually lirelline ascomata and the absence of carbonized excipular tissue. However, a couple of species produce short, almost rounded ascomata and then closely resemble those of the genus Chiodecton. The latter can be distinguished by its carbonized stromata and its hooked to biclavate ascospores (THOR 1990; SPARRIUS 2004). Also similar is *Sclerophyton*, which differs chiefly in its oblong ascospores with rounded ends (fusiform with acute ends in *Enterographa*). *Enterographa quassiaecola* was reported from Alagoas by SPARRIUS (2004) and is included in the key.

Key to species of *Enterographa*

1a. Ascospores 3-septate 2
1b. Ascospores 5–11-septate 3

2a. Ascomata short, aggregate in pseudostromata, with smooth margin; norstictic acid..... ***E. compunctula***
2b. Ascomata elongate, solitary, with byssoid margin; chemistry not tested..... ***E.*** aff. ***byssoidea***

3a. Ascomata solitary; disc pale; psoromic acid ..... ***E. anguinella***
3b. Ascomata in stellate clusters or aggregate in pseudostromata; no substances or norstictic acid in pseudostromata 4

4a. Norstictic acid in pseudostromata; ascospores (5–)7–11-septate, 30–50 µm long..... 5
4b. No substances; ascospores 7-septate, 20–40 µm long..... 6

4a. Ascomata 5–15 per pseudostroma; hymenium I+ blue (amyloid); ascospores 40–50 µm long ..... ***E. subquassiaecola***

4b. Ascospores 1–5 per pseudostromata; hymenium I+ orange-red, KI+ blue (hemyamyloid); ascospores 30–45 µm long.....***E. quassiaecola***

5a. Ascomata in stellate clusters; ascospores 20–30 µm long....***E. sipmanii***
5b. Ascomata aggregate in pseudostromata; ascospores 35–40 µm long .... ***E. chiodectonoides***

Enterographa anguinella (Nyl.) Redinger

Specimens examined. Alagoas: Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (forest along main trail), 50 m, *Cáceres A04-cortex* (F), *A05-041* (F).

Enterographa aff. ***byssoidea*** Lücking

Notes. This is most certainly an undescribed species which can not be formally established due to the sparse material. The most distinctive features are the dark hypothecium and the byssoid margin of the ascomata, otherwise only known from *Enterographa byssoidea*, a foliicolous species that differs by its pale hypothecium and 7-septate ascospores (SPARRIUS 2004).

Specimen examined. Alagoas: Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (forest along main trail), 50 m, *Cáceres A01-cortex* (F).

Enterographa chiodectonoides Cáceres & Lücking **spec. nova** (FIG. 13A)

Enterographa elixii ascosporis maioribus differt. — Typus. Alagoas: Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (closed forest), 50 m, *Cáceres 2002* (URM, holotype; F, isotype). — Paratypus. Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (forest along main trail), 50 m, *Cáceres A01-006* (B).

Description. Thallus crustose, corticolous, continuous, dispersed into irregular patches, 10–20 mm across, uneven to irregularly verrucose and minutely farinose, ecorticate, 30–70 µm thick, yellowish green, matt. Photobiont *Trentepohlia*; cells angular-rounded, 8–12 × 5–8 µm. Lirellae immersed in pseudostromata, 0.2–0.5 mm long and 0.05–0.15 mm broad; disc dark grey to black and sometimes thinly white pruinose; proper margin indistinct; pseudostromata erumpent to sessile, white, sharply contrasting with thallus, 100–150 µm high, ecorticate, filled with abundant grey crystals that dissolve in KOH, with algal cells in upper part. Excipulum prosoplectenchymatous, 20–50 µm thick, basally colorless but in upper part dark brown. Hypothecium 20–30 µm high, colorless. Epithecium distinct, 15–25 µm high, grey-brown. Hymenium 80–100 µm high, colorless, I+ blue, KI+

deep blue. Paraphyses richly branched and anastomosing. Asci 60–70 × 15–18 µm, I–, KI– except for KI+ blue, thin, broad, ring-shaped structure in tholus. Ascospores narrowly fusiform, 7-septate, slightly thick-walled, 35–40 × 3–5 µm. Pycnidia not observed. Chemistry: no substances detected by TLC.

Notes. At first glance, *Enterographa chiodectonoides* resembles a species of *Chiodecton*, because of the distinctive, prominent, white pseudostromata. However, the relatively broad, lirellate ascomata and the lack of carbonized stromatic structures place this species in *Enterographa*. The latter genus contains several species that produce pseudostromata, such as *E. compunctula*, *E. elixii*, and *E. kalbii*. Morphologically most similar is *E. elixii*, but that species differs in having smaller, 3-septate ascospores, a pale orange, K+ yellow hypothecium and a differently colored thallus. *Enterographa compunctula* has ascomata forming small dots and 3-septate ascospores, while *E. kalbii*, with 7-septate, though shorter ascospores, differs in the UV+ yellow pseudostromata (SPARRIUS 2004). A strange feature of *E. chiodectonoides* is the I+ blue hymenium (I+ orange-red in most other species), a rare feature in *Enterographa* but otherwise known from certain species of *Chiodecton* (THOR 1995).

Enterographa compunctula (Nyl.) Redinger (FIG. 13B)

Specimen examined. Alagoas: Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (closed forest), 50 m, *Cáceres & Lücking 01-0011* (B, F, URM).

Enterographa sipmanii Sparrius (FIG. 13C)

Specimen examined. PERNAMBUCO: Caruaru, Instituto Pernambucano de Pesquisas Agropecuárias (IPA), 8° 17' S, 35° 58' W, Caatinga (open thornbush), 500–600 m, *Cáceres & Lücking 00-0034b* (F).

Enterographa subquassiaecola Cáceres & Lücking **spec. nova** (FIG. 13D)

Echinoplaca quassiaecola pseudostromata maioribus excipulo fusco et hymenio I+ caeruleo differt. — Typus. PERNAMBUCO: Caruaru, Instituto Pernambucano de Pesquisas Agropecuárias (IPA), 8° 17' S, 35° 58' W, Caatinga (open thornbush), 500–600 m, *Cáceres & Lücking 00-0031* (B, holotypus).

Description. Thallus crustose, corticolous, continuous, dispersed into irregular patches, 10–20 mm across, uneven, ecorticate, 30–70 µm thick, green-grey, matt. Photobiont *Trentepohlia*; cells angular-rounded, 8–14 × 5–8 µm. Lirellae punctiform, 5–15 aggregate and immersed in pseudostromata, 0.05–0.1 mm diam.; disc brown-black; proper margin indistinct; pseudostromata

erumpent, green-grey, not sharply contrasting with thallus, 100–150 µm high, ecorticate, with algal cells in upper part, K+ yellow then forming red, needle-shaped crystals. Excipulum prosoplectenchymatous, 10–20 µm thick, dark brown. Hypothecium 20–30 µm high, colorless. Epithecium distinct, 15–25 µm high, pale brown. Hymenium 80–100 µm high, colorless, I+ blue, KI+ deep blue. Paraphyses richly branched and anastomosing. Asci 70–90 × 15–18 µm, I–, KI– except for KI+ blue, thin, broad, ring-shaped structure in tholus. Ascospores narrowly fusiform, 7–11-septate, slightly thick-walled, 40–50 × 4–5 µm. Pycnidia not observed. Chemistry: norstictic acid (in pseudostromata).

Notes. This new species would key out as *Enterographa quassiaecola* in the monograph of SPARRIUS (2004), with which it shares the presence of norstictic acid in the pseudostromata. However, several characteristics have convinced us that it deals with a different taxon. The ascomata are always aggregate 5–15 in distinct pseudostromata (up to five in *E. quassiaecola*), the excipulum is dark brown (pale to orange in *E. quassiaecola*), and the hymenium is I+ blue (I+ orange-red in *E. quassiaecola*). *Enterographa compunctula* is also similar in several aspects (pseudostromatic ascomata, norstictic acid, I+ blue hymenium), but has much shorter, 3-septate ascospores.

Eugeniella Lücking *et al*. (Pilocarpaceae)

Notes. Eugeniella is a newly established genus including species similar to *Fellhanera* but with larger apothecia forming a persistent, thick margin, a crystalline excipulum, and distinct, unbranched or little branched paraphyses (LÜCKING 2007). Superficially the genus resembles certain *Malcolmiella* species, but is clearly distinguished by its 3-7-septate ascospores.

Key to species of *Eugeniella*

1a. Pycnidia tubular; disc color grey-brown-black; paraphyses slightly branched ..... ***E. corallifera***
1b. Pycnidia absent; disc color brown-black; paraphyses unbranched ....***E. leucocheila***

Eugeniella corallifera (Lücking) Lücking, Sérus. & Kalb

Specimens examined. PERNAMBUCO: Caruaru, Brejo dos Cavalos, 8° 20' S, 35° 58' W, Brejo de Altitude (high altitude rainforest), 800–900 m, *Cáceres & Lücking 00-0599e* (B-600124028), *00-0609a* (F), *00-0676a* (F).

Eugeniella leucocheila (Tuck.) Lücking, Sérus. & Kalb

Specimen examined. PERNAMBUCO: Caruaru, Brejo dos Cavalos, 8° 20' S, 35° 58' W, Brejo de Altitude (high altitude rainforest), 800–900 m, *Cáceres & Lücking 00-0609b* (F).

Fellhanera Vězda (Pilocarpaceae)

Notes. Species of *Fellhanera* are characterized by their small, mostly brownish apothecia with thin or evanescent margin, a paraplectenchymatous excipulum, *Byssoloma*-type asci, and ellipsoid to oblong ascospores (LÜCKING 1997). Superficially most similar is the genus *Bacidina*, which has *Bacidia*-type asci and acicular ascospores (EKMAN 1996). The closely related genus *Byssoloma* differs by its byssoid excipulum.

Key to species of *Fellhanera*

1a. Ascospores 3-septate, 15–20 × 1.5–2 μm, about 10 times as long as broad ..... ***F.*** aff. ***rhaphidophylli***
1b. Ascospores 3–5-septate, 15–25 × 3.5–4.5 μm, 4–6 times as long as broad ..... ***F. microdiscus***

Fellhanera microdiscus (Vain.) Vězda

Specimen examined. ALAGOAS: Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (closed forest), 50 m, *Cáceres & Lücking 01-0103* (F, URM).

Fellhanera aff. ***rhaphidophylli*** (Rehm) Vězda

Notes. A probably undescribed species with apothecia similar to those of *Fellhanera rhaphidophylli* but with unusually narrow ascospores. The material is too scanty for a formal description.

Specimen examined. ALAGOAS: Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (forest along main trail), 50 m, *M. Cáceres A03-cortex* (F).

Fissurina Fée (Graphidaceae)

Notes. Species of *Fissurina* were formerly placed in *Graphis* and *Graphina*, respectively, depending on whether their ascospores are transversely septate or muriform. In a modern circumscription, *Fissurina* comprises taxa with immersed-erumpent to rarely sessile, fissurine lirellae, with the disc immersed and partly hidden between the strongly prominent margin. Ascospores are generally small and often I-negative (STAIGER 2002). Certain species,

such as *F. rufula*, might be difficult to separate from *Hemithecium*, a genus characterized by strongly developed labia that conceal the disc completely.

Key to species of *Fissurina*

1a. Ascospores 3-septate 2
1b. Ascospores submuriform 5

2a. Lirellae aggregate in pseudostromatic or linear clusters 3
2b. Lirellae solitary, evenly dispersed over thallus 4

3a. Lirellae elongate, branched, aggregate in pseudostromatic clusters ..... ***F. radiata***
3b. Lirellae short to rounded, aggregate in lines ..... ***F.*** aff. ***radiata***

4a. Lirellae immersed; labia weakly developed; ascospores 11–18 × 5–7 µm ..... ***F. dumastii***
4b. Lirellae prominent; labia well-developed; ascospores 20–24 × 9–13 µm ..... ***F. rufula***

5a. Lirellae immersed-erumpent, with divergent margins when old; ascospores 7–10 µm broad ..... ***F. incrustans***
5b. Lirellae erumpent to prominent, with thick subhymenial layer when old; ascospores 10–15 µm broad ..... ***F. instabilis***

Fissurina dumastii Fée (FIG. 13E)

Specimens examined. ALAGOAS: Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (closed forest), 50 m, *Cáceres & Lücking 01-0520d* (F), *01-0544* (B-600124211, F, URM, hb. Kalb). Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (forest along main trail), 50 m, *M. Cáceres A02-020* (B, F, URM), *A05-037c* (B), *A10-098a* (F), *A11-101* (URM), *A24-207* (B), *A26-223* (URM), *A37-285a* (URM), *A46-415* (F), *A46-429* (F), *A47-444a* (B), *A47-445e* (F). PERNAMBUCO: Bonito, Parque Municipal de Bonito, 8° 28' S, 35°43' W, Brejo de Altitude (high altitude rainforest), 800 m, *Cáceres & Lücking 00-0290* (B-600124030, F, URM), *00-0350* (F), *00-0351* (B-600124029, URM).

Fissurina incrustans Fée (FIG. 13F)

Specimen examined. ALAGOAS: Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (forest along main trail), 50 m, *M. Cáceres A16-140* (B, F).

Fissurina instabilis (Nyl.) Nyl. (FIG. 13G)

Specimens examined. ALAGOAS: Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (forest along main trail), 50 m, *M. Cáceres A01-008* (URM), *A24-206* (F), *A32-248* (B, URM), *A43-335* (B, F, URM), *A46-411* (URM), *A46-421b* (F), *A46-428b* (F).

Fissurina radiata Mont. (FIG. 13H)

Specimens examined. ALAGOAS: Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (forest along main trail), 50 m, *M. Cáceres A10-098b* (B, F), *A41-326* (B), *A44-348* (F, URM), *A46-417a* (F). PERNAMBUCO: Bonito, Parque Municipal de Bonito, 8° 28' S, 35°43' W, Brejo de Altitude (high altitude rainforest), 800 m, *Cáceres & Lücking 00-0352* (F), *00-0353* (F). Cabo de Santo Agostinho, Reserva Ecológica de Gurjaú, 8° 19' S, 35° 04' W, Mata Atlântica (closed forest), 30 m, *Cáceres & Lücking 00-0151* (B, F, URM). Igarassu, Refúgio Ecológico Charles Darwin, 7° 50' S, 34° 54' W, Mata Atlântica (closed forest), 20 m, *Cáceres & Lücking 00-0532* (F), *00-0533* (URM), *00-0534* (URM), *00-0537* (F).

Fissurina aff. ***radiata*** Mont.

Notes. No name was found for this material which is intermediate between a typical *Fissurina* and certain menbers of Thelotremataceae. The rounded individual apothecia resemble a tiny *Chapsa* or *Thelotrema*, but their anatomy points to *Fissurina*.

Specimens examined. PERNAMBUCO: Igarassu, Refúgio Ecológico Charles Darwin, 7° 50' S, 34° 54' W, Mata Atlântica (closed forest), 20 m, *Cáceres & Lücking 00-0491* (F), *00-0529* (F), *00-0536* (F).

Fissurina rufula (Mont.) Staiger

Specimen examined. RIO GRANDE DO NORTE: Baía Formosa, Reserva Particular do Patrimônio Natural (RPPN) Mata Estrela Senador Antônio Farias, 06° 22' S, 35° 01' W, Mata Atlântica (closed forest), 0 m, *M. Cáceres 01-0165* (B-600124174, F, URM).

Flakea O. E. Erikss.(Verrucariaceae)

Notes. Flakea is a monospecific genus described for an enigmatic, sterile lichen of uncertain systematic position (ERIKSSON 1992). The very thin thallus is squamulose to microfoliose with well-developed rhizines, with a structure unlike any other lichen. Certain similarities with *Agonimia* and *Psoroglaena* suggest placement in Verrucariaceae, but molecular data are needed to resolve its exact position within the lichenized Ascomycota.

Flakea papillata O. E. Erikss. (FIG. 14A)

Specimen examined. PERNAMBUCO: Recife, Barragem, Mata Atlântica, *M. Cáceres & R. Lücking 98-s.n.* (F, URM).

Glyphis Ach. (Graphidaceae)

Notes. The genus *Glyphis* originally included species of Graphidaceae with stromatic ascomata and colorless ascospores. In her thesis, STAIGER (2002) could show that species with solitary ascomata, both rounded and lirellate, are congeneric with the common *Glyphis cicatricosa*, and thus united species formerly placed in *Gyrostomum* and *Graphina* with *Glyphis*. This was confirmed by a molecular phylogenetic analysis. *Glyphis* thus includes species with very different apothecia morphology but uniform anatomy, hymenial structure and ascospore type.

Key to species of *Glyphis*

1a. Apothecia arranged in stromata, apothecial discs rounded to lirellate; ascospores 7–13-septate, 30–60 × 7–10 µm..... ***G. cicatricosa***
1b. Apothecia solitary; ascospores muriform..... 2

2a. Apothecial disc rounded, exposed; ascospores 30–45 × 12–16 µm..... ..... ***G. scyphulifera***
2b. Apothecial disc lirellate, concealed; ascospores 25–45 × 10–13 µm..... ..... ***G. substriatula***

Glyphis cicatricosa Ach. (FIG. 14B–C)

Specimens examined. ALAGOAS: Barra de São Miguel, Reserva Particular do Patrimônio Natural (RPPN) Rosa do Sol, 09° 51' S, 35° 53' W, Mata Atlântica (closed forest), 50 m, *M. Cáceres 01-0129* (B-600124180, F, URM). Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (forest along main trail), 50 m, *M. Cáceres A44-347* (URM). PERNAMBUCO: Cabo de Santo Agostinho, Reserva Ecológica de Gurjaú, 8° 19' S, 35° 04' W, Mata Atlântica (closed forest), 30 m, *Cáceres & Lücking 00-0222c* (F), *00-0237* (B-600124033, F), *00-0249* (URM). Caruaru, Instituto Pernambucano de Pesquisas Agropecuárias (IPA), 8° 17' S, 35° 58' W, Caatinga (open thornbush), 500–600 m, *Cáceres & Lücking 00-0002* (B-600124031, URM), *00-0003* (URM), *00-0004* (F), *00-0005* (F), *00-0132* (F). São Lourenço da Mata, Estação Ecológica de Tapacurá, 8° 02' S, 35° 09' W, Agreste (open dry forest), 100 m, *Cáceres & Lücking 98-0255* (F), *98-s.n. (a)* (F). SERGIPE: Itabi, Private property, 10° 06' S, 37° 54' W, Caatinga (thornbush), 100 m, *M. Cáceres 2161* (URM), *2164* (F, URM). Santa Luzia, Private property, 11° 19' S, 37° 27' W, Mata Atlântica (closed forest), *Cáceres & Lücking 00-0872* (URM), *00-0880* (URM). Ribeira, Mata Atlântica, *M. Cáceres 2060* (F).

Glyphis scyphulifera (Ach.) Staiger (FIG. 14D)

Specimens examined. ALAGOAS: Barra de São Miguel, Reserva Particular do Patrimônio Natural (RPPN) Rosa do Sol, 09° 51' S, 35° 53' W, Mata Atlântica (closed forest), 50 m, *M. Cáceres 01-0128* (B-600124179, F, URM), *01-0135* (B-600124182), *01-0141* (URM), *01-0143* (URM). Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro,

09° 37' S, 35° 58' W, Mata Atlântica (closed forest), 50 m, *Cáceres & Lücking 01-0084* (URM). PERNAMBUCO: Cabo de Santo Agostinho, Reserva Ecológica de Gurjaú, 8° 19' S, 35° 04' W, Mata Atlântica (closed forest), 30 m, *Cáceres & Lücking 00-0222d* (F), *00-0228* (F, URM). Caruaru, Instituto Pernambucano de Pesquisas Agropecuárias (IPA), 8° 17' S, 35° 58' W, Caatinga (open thornbush), 500–600 m, *Cáceres & Lücking 00-0096* (F), *00-0097* (B-600124044), *00-0098* (F), *00-0099* (B-600124045, URM), *00-0100* (F), *00-0101* (B-600124046). SERGIPE: Gararu, 9° 58' S, 37° 54' W, Caatinga (thornbush), 0–100 m, *M. Cáceres 2108* (URM), *2123* (F, URM), *s.n.* (F, URM).

Glyphis substriatula (Nyl.) Staiger (FIG. 14E)

Specimens examined. SERGIPE: Gararu, 9° 58' S, 37° 54' W, Caatinga (thornbush), 0–100 m, *M. Cáceres 2097* (F, URM).

Graphis Adans. (Graphidaceae)

Notes. In its traditional sense, *Graphis* included species with lirellate apothecia and colorless, transversely septate ascospores; it thus united a large number of unrelated species now known to belong to other genera (WIRTH & HALE 1963, 1978; ARCHER 2001a). In its revised, much more natural definition, *Graphis* now includes species with lirellate apothecia, well-developed, carbonized labia that usually conceal the disc, and colorless, I+ violet-blue, transversely septate to muriform ascospores (STAIGER 2002). Even in this revised sense, *Graphis* continues to be the largest genus in the family, with probably more than 300 species world-wide.

Key to species of *Graphis*

1a. Ascospores transversely septate or terminally muriform 2
1b. Ascospores entirely muriform 26

2a. Ascospores large, 50–140 µm long 3
2b. Ascospores small to medium-sized, 20–60 µm long..... 6

3a. Ascospores transversely septate; norstictic acid..... 4
3b. Ascospores terminally muriform; stictic acid or no substances 5

4a. Ascospores 11–25-septate, 50–120 × 9–18 µm; labia entire, thalline margin lateral..... ***G. marginata***
4b. Ascospores 13–19-septate, 95–115 × 17–21 µm; labia eventually striate, thalline margin complete but thin and often flaking off..... ***G. lumbricina***

5a. Labia entire, white pruinose, thalline margin complete; ascospores 15–21-septate with 0–1 longitudinal terminal septa, 6–8 per ascus, 75–95 × 11–14 μm; stictic acid ..... ***G. subturgidula***
5b. Labia striate, non pruinose, thalline margin lateral; ascospores 19–23-septate with 0–2 longitudinal terminal septa, 2–6 per ascus, 80–140 × 12–16 μm; no substances ..... ***G. vestitoides***

6a. Labia entire 7
6b. Labia striate 19

7a. Ascospores 7–17 septate, 30–60 × 7–11 μm; labia white pruinose ..... ***G. pavoniana***
7b. Ascospores 5-11-septate, 20–45 μm long 8

8a. Excipulum apically carbonized only; thallus ecorticate, farinose ..... ***G. glaucescens***
8b. Excipulum laterally to completely carbonized; thallus corticate or rarely partly ecorticate 9

9a. Excipulum laterally carbonized only, basally pale to orange or absent 10
9b. Excipulum completely carbonized, basally black 15

10a. Disc exposed, white pruinose; hymenium inspersed.. ***G. submarginata***
10b. Disc concealed; hymenium clear **11**

11a. Stictic acid; lirellae radiately branched ..... ***G. dendrogramma***
11b. Norstictic acid or no substances 12

12a. Norstictic acid 13
12b. No substances 14

13a. Lirellae immersed, thalline margin lateral; labia white pruinose ..... ***G. caesiella***
13b. Lirellae erumpent; thalline margin complete (apically thin); labia non-pruinose ..... ***G. kakaduensis***

14a. Lirellae wavy, thin; thallus often partly ecorticate ..... ***G. furcata***
14b. Lirellae straight, boat-shaped; thallus corticate ..... ***G. palmyrensis***

15a. Thalline margin absent or basally weakly developed 16
15b. Thalline margin lateral to complete 17

16a. Lirellae sessile (*Melaspilea*-like); thalline margin absent.. ***G. virescens***

16b. Lirellae prominent (*Opegrapha*-like); thalline margin often basally developed ..... ***G. geraensis***

17a. Ascospores 11-septate; thalline margin lateral (upper labia sharply delimited, black); lirellae sparsely branched ..... ***G. oxyclada***
17b. Ascospores 7-septate; thalline margin complete, thin or lateral, but different from above; lirellae richly branched 18

18a. Thalline margin complete, thin; lirellae radiately branched, 3–10 × 0.15–2 mm ..... ***G. pernambucoradians***
18b. Thalline margin lateral; lirellae forming stellate clusters, 1–5 × 0.07–0.15 mm ..... ***G. stellata***

19a. Ascospores 9–15-septate, 40–65 μm long 20
19b. Ascospores 5–9(–11)-septate, 20–45 μm long 21

20a. Lirellae erumpent; thalline margin lateral ..... ***G. rigidula***
20b. Lirellae prominent; thalline margin absent ..... ***G. striatula***

21a. Excipulum apically carbonized only; thallus ecorticate, farinose ..... ***G. glaucescens***
21b. Excipulum laterally to completely carbonized; thallus corticate 22

22a. Norstictic acid 23
22b. No substances 24

23a. Lirellae immersed; excipulum laterally to completely carbonized; thalline margin lateral; labia white pruinose ..... ***G. schiffneri***
23b. Lirellae prominent; excipulum completely carbonized; thalline margin basal; labia non-pruinose; ascospores 30–40 × 7–8 μm ..... ***G. parallela***

24a. Excipulum completely carbonized; lirellae prominent ..... ***G. dupaxana***
24b. Excipulum laterally carbonized; lirellae erumpent to prominent 25

25a. Lirellae erumpent; thalline margin lateral ..... ***G. tenella***
25b. Lirellae prominent; thalline margin absent ..... ***G. duplicata***

26a. Ascospores 30–40 × 9–11 μm; excipulum apically (to laterally) carbonized ..... ***G. paraserpens***
26b. Ascospores 70-250 μm long; excipulum laterally to completely carbonized 27

27a. Labia entire 28
27b. Labia striate 30

28a. Ascospores 150–250 × 25–30 µm, 1 per ascus; excipulum laterally carbonized only ..... ***G. pilarensis***
28b. Ascospores 80–120 µm long, 1–6 per acus; excipulum completely carbonized..... 29

29a. Ascospores 1–3 per ascus, 80–120 × 25–35 µm; hymenium clear .... ***G. carassensis***
29b. Ascospores 4–6 per ascus, 90–120 × 15–25 µm; hymenium inspersed. ..... ***G. argentea***

30a. Labia orange pruinose, K+ purple; anthraquinones present..... ..... ***G. chrysocarpa***
30b. Labia non pruinose, K–; no secondary chemistry 31

31a. Ascospores 90–120 × 15–25 µm; hymenium inspersed..... ***G. argentea***
31b. Ascospores up to 170 µm long; hymenium clear 32

32a. Ascospores 2–6 per ascus, 80–170 × 15–30 µm; lirellae prominent; thalline margin complete (apically thin)..... ***G. acharii***
32b. Ascospores 1 per ascus, 70–170 × 20–40 µm; lirellae erumpent; thalline margin lateral (upper labia sharply delimited, black).... ***G. macella***

Graphis acharii Fée (FIG. 14F)

Specimens examined. PERNAMBUCO: Bonito, Parque Municipal de Bonito, 8° 28' S, 35°43' W, Brejo de Altitude (high altitude rainforest), 800 m, *Cáceres & Lücking 00-0356* (URM), *00-0367* (hb. Kalb). SERGIPE: Ribeira, Mata Atlântica, *M. Cáceres 2057* (F).

Graphis argentea Lücking & Umaña (FIG. 14G)

Specimens examined. ALAGOAS: Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (closed forest), 50 m, *Cáceres & Lücking 01-0518a* (hb. Kalb), *01-0519* (F). PERNAMBUCO: Bonito, Parque Municipal de Bonito, 8° 28' S, 35°43' W, Brejo de Altitude (high altitude rainforest), 800 m, *Cáceres & Lücking 00-0358* (B-600124041), *00-0359* (F). Igarassu, Refúgio Ecológico Charles Darwin, 7° 50' S, 34° 54' W, Mata Atlântica (closed forest), 20 m, *Cáceres & Lücking 00-0496* (F), *00-0497* (B-600124042).

Graphis caesiella Vain.

Specimens examined. PERNAMBUCO: Caruaru, Instituto Pernambucano de Pesquisas Agropecuárias (IPA), 8° 17' S, 35° 58' W, Caatinga (open thornbush), 500–600 m, *Cáceres & Lücking 00-0012a* (F). Recife, Universidade Federal de Pernambuco (UFPE), secondary vegetation on campus, *Cáceres & Lücking 98-s.n.* (B, F, URM).

Graphis carassensis Vain. (FIG. 14H)

Specimen examined. ALAGOAS: Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (closed forest), 50 m, *Cáceres & Lücking 01-0019* (F).

Graphis chrysocarpa (Raddi) Spreng. (FIG. 15A)

Specimen examined. PERNAMBUCO: Caruaru, Brejo dos Cavalos, 8° 20' S, 35° 58' W, Brejo de Altitude (high altitude rainforest), 800–900 m, *Cáceres & Lücking 00-0641* (B, F, URM).

Graphis dendrogramma Nyl. (FIG. 15B)

Specimen examined. PERNAMBUCO: Recife, Universidade Federal de Pernambuco (UFPE), secondary vegetation on campus, *Cáceres & Lücking 98-s.n.* (F, URM).

Graphis dupaxana Vain. (FIG. 15C)

Specimen examined. PERNAMBUCO: Caruaru, Instituto Pernambucano de Pesquisas Agropecuárias (IPA), 8° 17' S, 35° 58' W, Caatinga (open thornbush), 500–600 m, *Cáceres & Lücking 00-0038* (B, F).

Graphis duplicata Ach.

Specimens examined. PERNAMBUCO: Bonito, Parque Municipal de Bonito, 8° 28' S, 35°43' W, Brejo de Altitude (high altitude rainforest), 800 m, *Cáceres & Lücking 00-0360* (URM). SERGIPE: Santa Luzia, Private property, 11° 19' S, 37° 27' W, Mata Atlântica (closed forest), *Cáceres & Lücking 00-0866* (B, F).

Graphis furcata Fée

Specimen examined. ALAGOAS: Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (forest along main trail), 50 m, *M. Cáceres A08-067* (F).

Graphis geraensis Redinger

Specimens examined. PERNAMBUCO: Caruaru, Brejo dos Cavalos, 8° 20' S, 35° 58' W, Brejo de Altitude (high altitude rainforest), 800–900 m, *Cáceres & Lücking 00-0650* (B). Igarassu, Refúgio Ecológico Charles Darwin, 7° 50' S, 34° 54' W, Mata Atlântica (closed forest), 20 m, *Cáceres & Lücking 00-0504* (F), *00-0505* (URM). Recife, Dois Irmãos, Mata Atlântica (closed forest), *Cáceres & Lücking 99-0504* (B).

Graphis glaucescens Fée (FIG. 15D)

Specimens examined. ALAGOAS: Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (closed forest), 50 m, *Cáceres &*

Lücking 01-0115 (B), *01-0528* (F), *01-0571* (F), *01-0575* (F), *01-0578* (F). Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (forest along main trail), 50 m, *M. Cáceres A04-035* (B, F), *A05-039a* (F), *A17-158* (URM), *A25-215* (F), *A34-265* (URM), *A36-280a* (URM), *A40-307* (URM), *A42-327b* (URM), *A44-351* (F), *A46-417c* (F), *A46-419* (F), *A46-423* (URM), *A46-424a* (F), *A46-425* (F), *A46-425c* (F), *A47-442* (B), *A47-444b* (B), *A47-445c* (F). PERNAMBUCO: Cabo de Santo Agostinho, Reserva Ecológica de Gurjaú, 8° 19' S, 35° 04' W, Mata Atlântica (closed forest), 30 m, *Cáceres & Lücking 00-0158* (B-600124039, F). Igarassu, Refúgio Ecológico Charles Darwin, 7° 50' S, 34° 54' W, Mata Atlântica (closed forest), 20 m, *Cáceres & Lücking 00-0484* (B-600124040, URM), *00-0495* (URM). RIO GRANDE DO NORTE: Baía Formosa, Reserva Particular do Patrimônio Natural (RPPN) Mata Estrela Senador Antônio Farias, 06° 22' S, 35° 01' W, Mata Atlântica (closed forest), 0 m, *M. Cáceres 01-0173* (B, duplicate, F, URM).

Graphis kakaduensis A. W. Archer (FIG. 15E)

Specimens examined. ALAGOAS: Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (closed forest), 50 m, *Cáceres & Lücking 01-0518a* (F), *01-0529b* (F). PERNAMBUCO: Cabo de Santo Agostinho, Reserva Ecológica de Gurjaú, 8° 19' S, 35° 04' W, Mata Atlântica (closed forest), 30 m, *Cáceres & Lücking 00-0222a* (F), *00-0250a* (F). Recife, Dois Irmãos, Mata Atlântica (closed forest), *Cáceres & Lücking 98-0517* (B). Recife, Universidade Federal de Pernambuco (UFPE), secondary vegetation on campus, *Cáceres & Lücking 98-s.n.* (F).

Graphis lumbricina Vain.

Specimen examined. PERNAMBUCO: Caruaru, Brejo dos Cavalos, 8° 20' S, 35° 58' W, Brejo de Altitude (high altitude rainforest), 800–900 m, *Cáceres & Lücking 00-0601a* (F).

Graphis macella Kremp. (FIG. 15F)

Specimen examined. PERNAMBUCO: Bonito, Parque Municipal de Bonito, 8° 28' S, 35°43' W, Brejo de Altitude (high altitude rainforest), 800 m, *Cáceres & Lücking 00-0357* (F).

Graphis cf. ***marginata*** Raddi

Specimen examined. SERGIPE: Itabi, Private property, 10° 06' S, 37° 54' W, Caatinga (thornbush), 100 m, *M. Cáceres 2176* (B, F, URM).

Graphis oxyclada Müll. Arg.

Specimen examined. PERNAMBUCO: Caruaru, Instituto Pernambucano de Pesquisas Agropecuárias (IPA), 8° 17' S, 35° 58' W, Caatinga (open thornbush), 500–600 m, *Cáceres & Lücking 00-0011a* (F).

Graphis palmyrensis Zahlbr.

Specimen examined. PERNAMBUCO: Recife, Universidade Federal de Pernambuco (UFPE), secondary vegetation on campus, *Cáceres & Lücking 98-s.n.* (F).

Graphis parallela (Müll. Arg.) Cáceres & Lücking **comb. nova** (FIG. 15G)

Graphis rimulosa var. *parallela* Müll. Arg., J. Linn. Soc., Bot., 29: 224. 1892.

Specimen examined. ALAGOAS: Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (closed forest), 50 m, *Cáceres & Lücking 01-0501* (B, F).

Graphis paraserpens Lizano & Lücking

Specimen examined. PERNAMBUCO: Igarassu, Refúgio Ecológico Charles Darwin, 7° 50' S, 34° 54' W, Mata Atlântica (closed forest), 20 m, *Cáceres & Lücking 00-0503* (F).

Graphis pavoniana Fée (FIG. 15H)

Specimens examined. ALAGOAS: Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (closed forest), 50 m, *Cáceres & Lücking 01-0520a* (F). PERNAMBUCO: Cabo de Santo Agostinho, Reserva Ecológica de Gurjaú, 8° 19' S, 35° 04' W, Mata Atlântica (closed forest), 30 m, *Cáceres & Lücking 00-0248* (URM).

Graphis pernambucoradians Cáceres & Lücking **spec. nova** (FIG. 16A)

Graphis caesiocarpa et *G. subamylacea* acidum norsticticum et acidum sticticum desunt differt. — Typus. PERNAMBUCO: Caruaru, Brejo dos Cavalos, 8° 20' S, 35° 58' W, Brejo de Altitude (high altitude rainforest), 800–900 m, *Cáceres & Lücking 00-0655* (F, holotypus; URM, isotypus).

Description. Thallus crustose, corticolous, 20–50 mm across and 30–70 µm thick, continuous, smooth, with cartilaginous cortex, pale green-grey. Photobiont *Trentepohlia*; cells angular-rounded, 6–12 µm diam. Lirellae flexuose, stellately branched, erumpent to prominent, with apically thin complete thalline margin, 3–10 mm long, 0.15–0.2 mm wide, 0.15–0.2 mm high; disc concealed; labia entire, apically grey-black to black; thalline margin laterally thick, pale green-grey. Excipulum basally closed and completely carbonized, 50–80 µm wide, basally 20–30 µm high, black; laterally covered by thick, corticate algiferous thallus lacking crystals; hypothecium prosoplectenchymatous, 10–20 µm high, colorless; hymenium 90–130 µm high, colorless, clear. Epithecium indistinct. Paraphyses unbranched. Asci clavate to fusiform, 80–100 × 12–16 µm. Ascospores 8 per ascus, oblong to narrowly ellipsoid, 7-septate, 25–35 × 5–8 µm, 4–5 times as long as wide, colorless, I+ violet-blue. Secondary chemistry: no substances detected by TLC.

Notes. Graphis pernambucoradians belongs in a difficult group of species that share the general morphology and anatomy of the lirellae and the ascospore type with *G. scripta* and related taxa but differ by their basally closed, completely carbonized excipulum. At least 25 names have been described in this group but none fits the present material. *Graphis caesiocarpa* Redinger and *G. subamylacea* Zahlbr. are morphologically very similar but produce norstictic and stictic acid, respectively. Among the species lacking lichen substances, *G. hyphosa* Staiger, *G. sitiana* Vain., *G. subvirginea* Nyl., *G. duplicata* var. *negrosina* Vain. and *G. dracenae* Vain. come closest, but differ as follows: *G. hyphosa* has lirellae aggregate in pseudostromata, *G. sitiana* has prominent lirellae and shorter, 3–5-septate ascospores, *G. subvirginea* has lirellae completely covered by a thick thalline layer, *G. duplicata* var. *negrosina* has short, boat-shaped lirellae, and *G. dracenae* has short lirellae and jet-black upper labia. *Graphis oxyclada* is also similar but has little branched lirellae with thick lateral thalline margin and jet-black labia.

Graphis pilarensis Cáceres & Lücking **spec. nova** (FIG. 16B)

Graphis cinerea excipulo in parte basali aperto et ascosporis maioribus differt. — Typus. ALAGOAS: Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (closed forest), 50 m, *Cáceres & Lücking 01-0514* (F, holotypus; B, isotypus).

Description. Thallus crustose, corticolous, 20–50 mm across and 50–100 µm thick, continuous, uneven, with cartilaginous cortex, pale green-grey; in section with clusters of calcium oxalate crystals. Lirellae straight, very rarely branched, prominent, with apically thin complete thalline margin, 1–5 mm long, 0.6–1.2 mm wide, 0.4–0.5 mm high; disc concealed; labia entire (but new labia eventually forming in old lirellae), apically grey- black but along the slit with thin white pruina; thalline margin laterally distinct, white-grey. Excipulum laterally carbonized, 70–150 µm wide, black, basally lacking; laterally covered by corticate algiferous thallus including clusters of crystals; hypothecium prosoplectenchymatous, 10–30 µm high, colorless to pale yellowish; hymenium 300–450 µm high, colorless, strongly inspersed (paraphyses and asci hardly visible), nubilous inspersion (crystals) rapidly disappearing in KOH but oil droplets remaining along paraphyses. Epithecium indistinct. Paraphyses unbranched. Asci fusiform, 200–300 × 30–40 µm. Ascospores single, oblong to almost cylindrical, muriform, 150–250 × 25–30 µm, 6–10 times as long as wide, colorless, I+ violet-blue. Secondary chemistry: no substances detected by TLC.

Notes. This new species is distinguished by its rather unusual combination of characters. The robust, mostly short lirellae resemble those of *G. triphora* Nyl. and *G. triphoroides* Nyl. and related species, but these have a clear

hymenium, different lirellae anatomy and different chemistry. The hymenial inspersion is of the same type as found in the *G. cinerea* aggregate, but all members of that group have a basally closed, completely carbonized excipulum. In addition, ascospores as large as those of *G. pilarensis*, which are among the largest in the genus, are not known from species in the *G. cinerea* aggregate. The only species with such large ascospores is *G. muscicola* (Kalb) Staiger, which differs clearly by its round, perithecioid apothecia, basally closed and completely carbonized excipulum, and clear hymenium.

Graphis rigidula Müll. Arg. (FIG. 16C)

Specimen examined. PERNAMBUCO: Cabo de Santo Agostinho, Reserva Ecológica de Gurjaú, 8° 19' S, 35° 04' W, Mata Atlântica (closed forest), 30 m, *Cáceres & Lücking 00-0240* (F).

Graphis schiffneri Zahlbr. (FIG. 16D)

Specimens examined. PERNAMBUCO: Caruaru, Instituto Pernambucano de Pesquisas Agropecuárias (IPA), 8° 17' S, 35° 58' W, Caatinga (open thornbush), 500–600 m, *Cáceres & Lücking 00-0012* (B, F, URM), *00-0015* (F, URM), *00-0016* (B, F), *00-0017* (F, URM), *00-0018* (F).

Graphis stellata Cáceres & Lücking **spec. nova** (FIG. 16E)

Graphis pernambucoradiante apotheciis minoribus et thallo verrucoso differt. —Typus. SERGIPE: Santa Luzia, Private property, 11° 19' S, 37° 27' W, Mata Atlântica (closed forest), *Cáceres & Lücking s.n.* (F, holotypus; URM, isotypus).

Description. Thallus crustose, corticolous, 20–30 mm across and 30–70 μm thick, continuous, irregularly and coarsely verrucose, with cartilaginous cortex, pale green-grey; in section incrusted with large clusters of calcium oxalate crystals. Photobiont *Trentepohlia*; cells angular-rounded, 6–12 μm diam. Lirellae flexuose, forming small, stellate clusters, prominent, with lateral thalline margin, 1–5 mm long, 0.07–0.15 mm wide, 0.12–0.15 mm high; disc concealed; labia entire, apically black; thalline margin laterally thin but distinct, pale green-grey. Excipulum basally closed and completely carbonized, 30–60 μm wide, basally 20–30 μm high, black; laterally covered by corticate algiferous thallus incrusted with clusters of calcium oxalate crystals; hypothecium prosoplectenchymatous, 10–20 μm high, colorless; hymenium 80–100 μm high, colorless, clear. Epithecium indistinct. Paraphyses unbranched. Asci clavate to fusiform, 80–90 × 12–16 μm. Ascospores 8 per ascus, oblong to narrowly ellipsoid, 7-septate, 20–30 × 6–8 μm, 3–4 times as long as wide, colorless, I+ violet-blue. Secondary chemistry: no substances detected by TLC.

Notes. Graphis stellata is closely related to the newly described *G. pernambucoradians*, and for some time was thought to represent an extreme form of the latter. However, although lirellae anatomy and ascospore type are the same, there are several important differences: the lirellae are much more delicate and instead of one branched lirella covering much of the thallus, they form numerous small, stellate clusters. In addition, the apical part of the labia is always exposed and black, the lirellae are more prominent with thinner and steeper lateral margin, and the thallus is irregularly verrucose rather than smooth. None of these differences alone would probably justify recognizing this material as a different species, but the combination of differences suggests that it deals with a distinct taxon.

Graphis striatula (Ach.) Spreng.

Specimen examined. PERNAMBUCO: Caruaru, Brejo dos Cavalos, 8° 20' S, 35° 58' W, Brejo de Altitude (high altitude rainforest), 800–900 m, *Cáceres & Lücking 00-0651* (F).

Graphis submarginata Lücking

Specimen examined. PERNAMBUCO: Caruaru, Instituto Pernambucano de Pesquisas Agropecuárias (IPA), 8° 17' S, 35° 58' W, Caatinga (open thornbush), 500–600 m, *Cáceres & Lücking 00-0014* (B, F).

Graphis subturgidula Lücking & Sipman (FIG. 16F)

Specimen examined. SERGIPE: Ribeira, Mata Atlântica, *M. Cáceres 2030a* (F, URM).

Graphis tenella Ach. (FIG. 16G)

Specimens examined. PERNAMBUCO: Cabo de Santo Agostinho, Reserva Ecológica de Gurjaú, 8° 19' S, 35° 04' W, Mata Atlântica (closed forest), 30 m, *Cáceres & Lücking 00-0222b* (F), *00-0250b* (F).

Graphis vestitoides (Fink) Staiger

Specimen examined. PERNAMBUCO: Igarassu, Refúgio Ecológico Charles Darwin, 7° 50' S, 34° 54' W, Mata Atlântica (closed forest), 20 m, *Cáceres & Lücking 00-0498* (B-600124043, URM).

Graphis virescens Müll. Arg. (FIG. 16H)

Specimens examined. PERNAMBUCO: Caruaru, Brejo dos Cavalos, 8° 20' S, 35° 58' W, Brejo de Altitude (high altitude rainforest), 800–900 m, *Cáceres & Lücking 00-0549* (URM). Igarassu, Refúgio Ecológico Charles Darwin, 7° 50' S, 34° 54' W, Mata Atlântica (closed forest), 20 m, *Cáceres & Lücking 00-0502* (B), *00-0501* (F).

Haematomma A. Massal. (Lecanoraceae)

Notes. The genus *Haematomma* is easily recognized by its lecanorine apothecia with orange-red to blood-red apothecial discs, in combination with transversely septate to muriform ascospores (STAIGER & KALB 1995). Until recently, the genus was placed in its own family (ELIX 2004), but several authors have argued that it should be placed in Lecanoraceae, which is confirmed by unpublished molecular data (NELSEN *et al.* 2006). *Haematomma* is most diverse at mid elevations in the tropics, and only two species were found in the present material.

Key to species of *Haematomma*

1a. Thallus sorediate; ascospores 9–13-septate, 45–60 × 4.5–6 μm; thallus with lichexanthone; apothecial pigment haematommone ....***H. leprarioides***

1a. Thallus non-sorediate; ascospores 5–7-septate, 30–50 × 3.5–5 μm; thallus with atranorin; apothecial pigment russulone.....***H. persoonii***

Haematomma leprarioides (Vain.) Vain. (FIG. 17A)

Specimens examined. ALAGOAS: Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (closed forest), 50 m, *Cáceres & Lücking 01-0018* (B-600124175, F), *01-0006* (B-600124214).

Haematomma personii (Fée) A. Massal. (FIG. 17B)

Specimens examined. PERNAMBUCO: Caruaru, Brejo dos Cavalos, 8° 20' S, 35° 58' W, secondary vegetation (fence posts), 800–900 m, *Cáceres & Lücking 00-0805b* (B-600124145), *00-0803b* (F), *00-0806c* (F). Caruaru, Instituto Pernambucano de Pesquisas Agropecuárias (IPA), 8° 17' S, 35° 58' W, Caatinga (open thornbush), 500–600 m, *Cáceres & Lücking 00-0082* (F), *00-0084b* (F), *00-0090* (B-600124144), *00-0091* (F, URM), *00-0092* (B-600124143, URM), *00-0093c* (F), *00-0094* (F), *00-0095* (URM). Caruaru, Instituto Pernambucano de Pesquisas Agropecuárias (IPA), 8° 17' S, 35° 58' W secondary vegetation (open area in front of main building), 500–600 m, *Cáceres & Lücking 00-0128* (B-600124146), *00-0116* (B-600124148), *00-0115* (F), *00-0117* (F), *00-0124* (F), *00-0126* (URM), *00-0128* (URM). SERGIPE: Gararu, 9° 58' S, 37° 54' W, Caatinga (thornbush), 0–100 m, *M. Cáceres 2133* (F), *2135* (F), *2149a* (F), *2153* (F), *2115b* (URM).

Hafellia Kalb, H. Mayrhofer & Scheid. (Physciaceae)

Notes. Hafellia is characterized by its inspersed hymenium and mostly strong endospore thickenings in the ascospores (MARBACH 2000). The species found here can be distinguished from *Baculifera* and *Cratiria* also by the usually smaller, often brown-black apothecia with thinner margin and the absence of a brown prothallus.

Key to species of *Hafellia*

1a. Epihymenium K+ violet or yellow green; ascospores 15–22 × 6–8 µm; norstictic acid 2
1b. Epihymenium K–; ascospores larger; atranorin 3

2a. Epihymenium K+ violet; ascospores smooth ..... ***H. bahiana***
2b. Epihymenium K+ yellow green; ascospores ornamented . ***H. curatellae***

3a. Ascospores 25–35 × 9–14 µm, ornamented ..... ***H. demutans***
3b. Ascospores 30–40 × 12–16 µm, smooth ..... ***H. parastata***

Hafellia bahiana (Malme) Sheard (FIG. 17C)

Specimen examined. ALAGOAS: Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (closed forest), 50 m, *Cáceres & Lücking 01-0513* (B, F, URM).

Hafellia curatellae (Malme) Marbach (FIG. 17D)

Specimen examined. PERNAMBUCO: Caruaru, Instituto Pernambucano de Pesquisas Agropecuárias (IPA), 8° 17' S, 35° 58' W, Caatinga (open thornbush), 500–600 m, *Cáceres & Lücking 00-0068a* (F).

Hafellia demutans (Stirton) Pußwald (FIG. 17E)

Specimens examined. PERNAMBUCO: Caruaru, Instituto Pernambucano de Pesquisas Agropecuárias (IPA), 8° 17' S, 35° 58' W, Caatinga (open thornbush), 500–600 m, *Cáceres & Lücking 00-0070* (B-600124048), *00-0071* (F).

Hafellia parastata (Nyl.) Kalb (FIG. 17F)

Specimen examined. PERNAMBUCO: Caruaru, Instituto Pernambucano de Pesquisas Agropecuárias (IPA), 8° 17' S, 35° 58' W, secondary vegetation (open area in front of main building), 500–600 m, *Cáceres & Lücking 00-0129* (B-600124208, F).

Helminthocarpon Fée (Arthoniaceae)

Notes. Helminthocarpon is an unusual genus of uncertain taxonomic position, characterized by its lirellate ascomata with well-developed walls and hamathecium of the *Crypthecia*-type, lacking hymenial jelly (AWASTHI & JOSHI 1979; APTROOT 1999). The C+ red reaction of the lirellae is reminescent of *Dyplolabia*, but the two genera differ fundamentally in their ascomata anatomy. There seems to be only one common species in the Neotropics.

Helminthocarpon leprevostii Fée (FIG. 17G)

Specimens examined. PERNAMBUCO: Caruaru, Instituto Pernambucano de Pesquisas Agropecuárias (IPA), 8° 17' S, 35° 58' W, secondary vegetation (open area in front of main building), 500–600 m, *Cáceres & Lücking 00-0009* (B, F, URM), *00-0008* (F), *00-0007* (URM). São Lourenço da Mata, Estação Ecológica de Tapacurá, 8° 02' S, 35° 09' W, Agreste (open dry forest), 100 m, *Cáceres & Lücking 98-0257* (F). SERGIPE: Itabi, Private property, 10° 06' S, 37° 54' W, Caatinga (thornbush), 100 m, *M. Cáceres 2188* (B, F). Ribeira, Mata Atlântica, *M. Cáceres 2048* (F, URM).

Hemithecium Trevis. (Graphidaceae)

Notes. Hemithecium is most similar to *Graphis* in terms of lirellae morphology and anatomy, but differs in the complete absence of labia carbonization (STAIGER 2002). Currently the genus includes both species with colorless and with brown ascospores, but unpublished molecular analyses indicate that the brown-spored species centered around the widespread *H. chrysentheron* are unrelated to *Hemithecium* s.str.

Key to species of *Hemithecium*

1a. Ascospores colorless; hymenium clear ..... ***H. chlorocarpum***
1b. Ascospores brown; hymenium inspersed ..... ***H. chrysentheron***

Hemithecium chlorocarpum (Fée) Trevis.

Specimen examined. PERNAMBUCO: Bonito, Parque Municipal de Bonito, 8° 28' S, 35°43' W, Brejo de Altitude (high altitude rainforest), 800 m, *Cáceres & Lücking 00-0371* (B-600124071, F).

Hemithecium chrysentheron (Mont.) Trevis. (FIG. 17H)

Specimen examined. PERNAMBUCO: Bonito, Parque Municipal de Bonito, 8° 28' S, 35°43' W, Brejo de Altitude (high altitude rainforest), 800 m, *Cáceres & Lücking 00-0373* (B-600124070, F).

Herpothallon Tobler (Roccellaceae)

Notes. The genus *Herpothallon* is based on the widespread and common *lichen H. sanguineum*, more recently known as *Chiodecton sanguineum* and then as *Cryptothecia rubrocincta* (THOR 1991). A survey of tropical species of *Cryptothecia* s.lat. (APTROOT *et al.*, in prep.), however, indicates that there are certain differences between *Herpothallon* and *Cryptothecia* s.str. which deserve recognition at genus rank, and that *Herpothallon* is perhaps better placed in Roccellaceae. Species of *Herpothallon* have a thicker, almost byssoid thallus, and commonly produce felty isidia similar to those in *Dichosporidium*, while *Cryptothecia* s.str. is usually fertile and rarely

produces isidia. Also, the ascomata of *Herpothallon*, thus far found in one species, are very different from those of *Cryptothecia*. *Herpothallon rubrocinctum* was reported, supposedly as a basidiolichen, from Pernambuco by XAVIER FILHO (1979). In expectation of a forthcoming revision of this genus (APTROOT *et al.*, in prep.), we have not assigned species names to six of the seven taxa distinguished here.

Key to species of *Herpothallon*

1a. Thallus (isidia) and/or prothallus with orange or red pigment 2
1b. Thallus (isidia) and prothallus lacking such pigments, grey to black .. 3

2a. Prothallus and isidia orange..... ***H.*** spec. A
2b. Prothallus and isidia red .....***H. rubrocinctum***

3a. Prothallus black .....***H.*** spec. E
3b. Prothallus white or brown 4

4a. Thallus thin; isidia cylindrical, sparse 5
4b. Thallus thick; isidia fuzzy to coralloid, abundant 6

5a. Prothallus brown.....***H.*** spec. C
5b. Prothallus white .....***H.*** spec. F

6a. Isidia fuzzy ..... ***H.*** spec. D
6b. Isidia coralloid .....***H.*** spec. B

Herpothallon rubrocinctum (Ehrenb.) Aptroot & Lücking (FIG. 18D)

Specimens examined. PERNAMBUCO: Bonito, Parque Municipal de Bonito, 8° 28' S, 35°43' W, Brejo de Altitude (high altitude rainforest), 800 m, *Cáceres & Lücking 00-0286* (B-600124238, duplicate, F, URM). Cabo de Santo Agostinho, Reserva Ecológica de Gurjaú, 8° 19' S, 35° 04' W, Mata Atlântica (closed forest), 30 m, *Cáceres & Lücking 00-0140* (URM), *00-0141* (URM). Caruaru, Brejo dos Cavalos, 8° 20' S, 35° 58' W, Brejo de Altitude (high altitude rainforest), 800–900 m, *Cáceres & Lücking 00-0551* (F), *00-0619* (F), *00-0620* (B-600124237, F), *00-0621* (URM), *00-0622* (F), *00-0623* (F), *00-0624* (F), *00-0625* (URM), *00-0626* (B-600124256), *00-0627* (F).

Herpothallon spec. A (FIG. 18A)

Specimens examined. PERNAMBUCO: Bonito, Parque Municipal de Bonito, 8° 28' S, 35°43' W, Brejo de Altitude (high altitude rainforest), 800 m, *Cáceres & Lücking 00-0285* (F), *00-0303* (F).

Herpothallon spec. B (FIG. 18B)

Specimens examined. ALAGOAS: Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (closed forest), 50 m, *Cáceres & Lücking 01-0504* (F), *s.n.* (F). Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (forest along main trail), 50 m, *M. Cáceres A38-291* (F).

Herpothallon spec. C

Specimen examined. ALAGOAS: Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (forest along main trail), 50 m, *M. Cáceres A09-074* (F).

Herpothallon spec. D (FIG. 18C)

Specimens examined. PERNAMBUCO: Bonito, Parque Municipal de Bonito, 8° 28' S, 35°43' W, Brejo de Altitude (high altitude rainforest), 800 m, *Cáceres & Lücking 00-0283* (F, URM), *00-0284* (F).

Herpothallon spec. E

Specimens examined. ALAGOAS: Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (forest along main trail), 50 m, *M. Cáceres A02-021* (F), *A40-304* (F), *A40-306* (F).

Herpothallon spec. F

Specimens examined. ALAGOAS: Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (forest along main trail), 50 m, *M. Cáceres A14-131* (F), *A24-200* (F), *A25-217* (F).

Heterodermia Trevis. (Physciaceae)

Notes. Heterodermia is a species-rich genus in tropical montane regions (SWINSCOW & KROG 1976), and only one species was found in the present collections. The genus is distinguished from *Physcia* by the prosoplectenchymatous upper cortex and absence of a lower cortex in most species.

Heterodermia dissecta (Kurok.) D. D. Awasthi

Specimen examined. PERNAMBUCO: Cabo de Santo Agostinho, Reserva Ecológica de Gurjaú, 8° 19' S, 35° 04' W, secondary vegetation (open area), 30 m, *Cáceres & Lücking s.n.* (F).

Laurera Reichenb. (Trypetheliaceae)

Notes. The genus *Laurera* traditionally includes species of Trypetheliaceae with solitary to aggregate perithecia and muriform ascospores, and a mo-

dern revision is needed to clarify its exact circumscription (HARRIS 1986, 1995). *Laurera* s.str. should probably include species with both transversely septate and muriform ascospores having solitary to loosely aggregate perithecia immersed in thalline warts.

Key to species of *Laurera*

1a. Ascospores 2 per ascus; ostiole lateral ..... ***L. sphaeroides***
1b. Ascospores 4 per ascus; ostiole apical..... ***L. megasperma***

Laurera megasperma (Mont.) Riddle (FIG. 18E)

Specimens examined. ALAGOAS: Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (closed forest), 50 m, *M. Cáceres 2015* (F, URM). PERNAMBUCO: Caruaru, Brejo dos Cavalos, 8° 20' S, 35° 58' W, Brejo de Altitude (high altitude rainforest), 800–900 m, *Cáceres & Lücking 00-0628* (B-600124049, F).

Laurera sphaeroides (Mont.) Müll. Arg. (FIG. 18F)

Specimen examined. PERNAMBUCO: Caruaru, Brejo dos Cavalos, 8° 20' S, 35° 58' W, Brejo de Altitude (high altitude rainforest), 800–900 m, *Cáceres & Lücking 00-0629* (F).

Lecanactis Körb. (Roccellaceae)

Notes. Lecanactis resembles certain species of *Lecanora* superficially, such *as L. caesiorubella*, but can be easily distinguished by its carbonized excipulum and *Opegrapha*-type hymenium, asci, and ascospores (EGEA & TORRENTE 1994). There is only one widespread and abundant neotropical species.

Lecanactis epileuca (Nyl.) Tehler (FIG. 18G)

Specimens examined. ALAGOAS: Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (closed forest), 50 m, *Cáceres & Lücking 01-0076* (B, F, URM), *01-0526* (B, F, URM), *Cáceres s.n.* (F, URM). Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (forest along main trail), 50 m, *M. Cáceres A42-324f* (F), *A45-360* (B, F, URM). PERNAMBUCO: Bonito, Parque Municipal de Bonito, 8° 28' S, 35°43' W, Brejo de Altitude (high altitude rainforest), 800 m, *Cáceres & Lücking 00-0336* (B, F, URM). Caruaru, Brejo dos Cavalos, 8° 20' S, 35° 58' W, Brejo de Altitude (high altitude rainforest), 800–900 m, *Cáceres & Lücking 00-0001* (F). SERGIPE: Areia Branca, Reserva Ecológica Serra de Itabaiana, 10° 45' S, 37° 20' W, Mata Atlântica (closed forest), 500 m, *Cáceres & Lücking 2206* (B, F, URM).

Lecanographa Egea & Torrente (Roccellaceae)

Notes. The genus *Lecanographa* is closely related to *Lecanactis* and differs chiefly in the lirellate rather than rounded ascomata, in combination with minor anatomical details such as its slightly different ascus type (EGEA & TORRENTE 1994; EGEA *et al.* 2004).

Lecanographa lyncea (Sm.) Egea & Torrente (FIG. 18H)

Specimens examined. PERNAMBUCO: Caruaru, Instituto Pernambucano de Pesquisas Agropecuárias (IPA), 8° 17' S, 35° 58' W, Caatinga (open thornbush), 500–600 m, *Cáceres & Lücking 00-0113* (B), *00-0114* (B, F, URM), *00-0130b* (F), *00-0131b* (F), *00-0114* (URM).

Lecanora Ach. (Lecanoraceae)

Notes. Lecanora is one of the largest lichen genera and is also diverse in the tropics in appropriate habitats (LUMBSCH *et al.* 1996; GUDERLEY 1999). Apart from thallus and apothecial chemistry and hypothecium color, the presence of crystals and pigments in the amphithecium, parathecium, and epithecium are important characters to separate species.

Key to species of *Lecanora*

1a. Hypothecium dark 2
1b. Hypothecium pale..... 5

2a. Hypothecium K+ dark red (boryquinone); epithecium with crystals, crystals and pigment dissolving in K; parathecium without crystals; disc color red-brown; ascospores 10–13 × 6–8 µm.....***L. hypocrocina***
2b. Hpothecium K–; epithecium without crystals 3

3a. Parathecium without crystals; zeorine..... ***L. coronulans***
3b. Parathecium with crystals; 2'-O-methylperlatolic acid..... 4

4a. Apothecial disc black-brown; ascospores 14–20 × 9–12 µm.....
.....***L. concilians***
4b. Apothecial disc red-brown to dark brown; ascospores 11–15 × 7–10 µm.....***L. concilianda***

5a. Apothecial disc white pruinose; amphithecium with small crystals; norstictic acid.....***L. caesiorubella***
5b. Apothecial disc non-pruinose; amphithecium with large crystals; secondary chemistry different 6

6a. Epithecium without crystals; pigment not dissolving in K; apothecial disc red-brown; zeorin and chodatin ..... ***L. tropica***

6b. Epithecium with crystals, crystals and pigment dissolving in K; apothecial disc pale yellow to beige; secondary chemistry different 7

7a. Apothecial disc pale yellow; thallus yellow-green; xanthones .... ***L.*** spec.
7b. Apothecial disc beige; thallus grey to green-grey; secondary chemistry different 8

8a. Thallus green-grey; usnic acid..... ***L. achroa***
8b. Thallus grey; 2'-O-methylperlatolic acid..... ***L. helva***

Lecanora achroa Nyl. (FIG. 19A)

Specimens examined. ALAGOAS: Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (closed forest), 50 m, *Cáceres & Lücking 01-0083* (F). PERNAMBUCO: Cabo de Santo Agostinho, Reserva Ecológica de Gurjaú, 8° 19' S, 35° 04' W, Mata Atlântica (closed forest), 30 m, *Cáceres & Lücking 00-0226* (F), *00-0223* (URM). Caruaru, Instituto Pernambucano de Pesquisas Agropecuárias (IPA), 8° 17' S, 35° 58' W, Caatinga (open thornbush), 500–600 m, *Cáceres & Lücking 00-0066* (F), *00-0067* (B, F), *00-0068b* (F). Sergipe: Gararu, 9° 58' S, 37° 54' W, Caatinga (thornbush), 0–100 m, *M. Cáceres 2152b* (F), *2115c* (URM).

Lecanora caesiorubella Ach. (FIG. 19B)

Specimens examined. PERNAMBUCO: Caruaru, Instituto Pernambucano de Pesquisas Agropecuárias (IPA), 8° 17' S, 35° 58' W, Caatinga (open thornbush), 500–600 m, *Cáceres & Lücking 00-0086* (F). Sergipe: Gararu, 9° 58' S, 37° 54' W, Caatinga (thornbush), 0–100 m, *M. Cáceres 2099* (B, F, URM), *2152a* (F, URM), *s.n.* (F, URM).

Lecanora concilianda Vain. (FIG. 19C)

Specimen examined. PERNAMBUCO: Cabo de Santo Agostinho, Reserva Ecológica de Gurjaú, 8° 19' S, 35° 04' W, Mata Atlântica (closed forest), 30 m, *Cáceres & Lücking 00-0231* (B, F, URM).

Lecanora concilians Nyl. (FIG. 19D)

Specimen examined. SERGIPE: Itabi, Private property, 10° 06' S, 37° 54' W, Caatinga (thornbush), 100 m, *M. Cáceres 2178* (F).

Lecanora coronulans Nyl. (FIG. 19E)

Specimens examined. PERNAMBUCO: Bonito, Parque Municipal de Bonito, 8° 28' S, 35°43' W, Brejo de Altitude (high altitude rainforest), 800 m, *Cáceres & Lücking 00-0295* (B, F). Caruaru, Instituto Pernambucano de Pesquisas Agropecuárias (IPA), 8° 17' S, 35° 58' W, Caatinga (open thornbush), 500–600 m, *Cáceres & Lücking 00-0058a* (F).

Lecanora helva Stizenb. (FIG. 19F)

Specimens examined. PERNAMBUCO: Caruaru, Brejo dos Cavalos, 8° 20' S, 35° 58' W, secondary (fence posts), 800–900 m, *Cáceres & Lücking 00-0806b* (F). Recife, Universidade Federal de Pernambuco (UFPE), secondary vegetation on campus, *Cáceres & Lücking 98-s.n.* (F).

Lecanora hypocrocina Nyl. (FIG. 19G)

Specimens examined. PERNAMBUCO: Caruaru, Instituto Pernambucano de Pesquisas Agropecuárias (IPA), 8° 17' S, 35° 58' W, Caatinga (open thornbush), 500–600 m, *Cáceres & Lücking 00-0081* (F), *00-0085* (F). Caruaru, Instituto Pernambucano de Pesquisas Agropecuárias (IPA), 8° 17' S, 35° 58' W, secondary vegetation (open area in front of main building), 500–600 m, *Cáceres & Lücking 00-0127* (URM). SERGIPE: Gararu, 9° 58' S, 37° 54' W, Caatinga (thornbush), 0–100 m, *M. Cáceres 2098* (B, F, URM), *2103a* (URM), *2141* (B, F), *2125a* (F), *2136* (F), *2140* (F), *2149b* (F).

Lecanora tropica Zahlbr. (FIG. 19H)

Specimens examined. PERNAMBUCO: Cabo de Santo Agostinho, Reserva Ecológica de Gurjaú, 8° 19' S, 35° 04' W, Mata Atlântica (closed forest), 30 m, *Cáceres & Lücking 00-0232* (B, F). Caruaru, Brejo dos Cavalos, 8° 20' S, 35° 58' W, secondary (fence posts), 800–900 m, *Cáceres & Lücking 00-0808c* (F). Caruaru, Instituto Pernambucano de Pesquisas Agropecuárias (IPA), 8° 17' S, 35° 58' W, Caatinga (open thornbush), 500–600 m, *Cáceres & Lücking 00-0105* (F). Recife, Universidade Federal de Pernambuco (UFPE), secondary vegetation on campus, *Cáceres & Lücking 98-s.n.* (URM).

Lecanora spec.

Specimens examined. PERNAMBUCO: Caruaru, Instituto Pernambucano de Pesquisas Agropecuárias (IPA), 8° 17' S, 35° 58' W, Caatinga (open thornbush), 500–600 m, *Cáceres & Lücking 00-0083b* (F). SERGIPE: Gararu, 9° 58' S, 37° 54' W, Caatinga (thornbush), 0–100 m, *M. Cáceres 2103b* (URM), *2106b* (F), *2107a* (F), *2113b* (F).

Lepraria Ach. (Stereocaulaceae)

Notes. Lepraria traditionally included sterile crustose lichens with leprose-farinose-sorediate-effuse thalli of uncertain taxonomic affinity. Recently, it could be shown that *Lepraria* s.str. is a reduced member of the Stereocaulaceae (EKMAN & TØNSBERG 2002; MYLLYS *et al.* 2005). Genuine species of *Lepraria* are comparatively rare in the tropics and restricted to certain humid conditions.

Lepraria spec.

Specimen examined. PERNAMBUCO: Igarassu, Refúgio Ecológico Charles Darwin, 7° 50' S, 34° 54' W, Mata Atlântica (closed forest), 20 m, *Cáceres & Lücking 00-0403* (F).

Letrouitia Haf. & Bellem. (Letrouitiaceae)

Notes. Letrouitia is a very typical member of tropical crustose lichen communities and easily recognized by its brightly colored apothecia, in combination with a usually yellow-green or olive thallus (HAFELLNER 1981). The ascospores resemble those of Graphidaceae but are of a different type. Species of *Caloplaca* and *Brigantiaea* might resemble *Letrouitia* but can be distinguished by their different ascospores, thin-walled in *Brigantiaea* and polarilocular in *Caloplaca*, among other features.

Key to species of *Letrouitia*

1a. Ascospores transversely septate; apothecial margin orange-yellow .... ***L. domingensis***
1b. Ascospores muriform; apothecial margin purple to orange-red..... 2

2a. Apothecial margin purple .....***L. subvulpina***
2b. Apothecial margin orange-red.....***L. vulpina***

Letrouitia domingensis (Pers.) Haf. & Bellem. (FIG. 20A)

Specimens examined. ALAGOAS: Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (closed forest), 50 m, *Cáceres & Lücking 01-0030* (B, F, URM), *01-0033* (B-600124260, F, URM), *01-0058* (B-600124258, URM), *01-0063* (F, URM), *01-0090* (F), *01-0164* (B-600124261, URM), *01-0558* (F), *2003* (F, URM), *2022* (B-600124274, F), *2024* (F). Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (forest along main trail), 50 m, *Cáceres A12-119a* (F, URM), *A13-121a* (F), *A13-122* (URM), *A17-150* (URM), *A21-184a* (B), *A27-231* (B, URM), *A37-281a* (URM), *A37-286* (B, F, URM). PERNAMBUCO: Cabo de Santo Agostinho, Reserva Ecológica de Gurjaú, 8° 19' S, 35° 04' W, Mata Atlântica (closed forest), 30 m, *Cáceres & Lücking 00-0192* (B-600124103, F), *00-0193b* (F). Cabo de Santo Agostinho (Barragem), Reserva Ecológica de Gurjaú, 8° 19' S, 35° 04' W, Mata Atlântica (closed forest), 30 m, *Cáceres & Lücking 98-s.n.* (F).São Lourenço da Mata, Estação Ecológica de Tapacurá, 8° 02' S, 35° 09' W, Agreste (open dry forest), 100 m, *Cáceres & Lücking 98-s.n. (b)* (F), *98-0259* (URM). SERGIPE: Ribeira, Mata Atlântica, *M. Cáceres 2038* (B, F, URM).

Letrouitia subvulpina (Nyl.) Haf. (FIG. 20B)

Specimens examined. ALAGOAS: Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (forest along main trail), 50 m, *Cáceres A35-271* (URM), *A35-273* (B, F, URM). PERNAMBUCO: Cabo de Santo Agostinho, Reserva Ecológica de Gurjaú, 8° 19' S, 35° 04' W, Mata Atlântica (closed forest), 30 m, *Cáceres & Lücking 00-0195* (B-600124053).

Letrouitia vulpina (Tuck.) Haf. & Bellem.

Specimens examined. ALAGOAS: Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (closed forest), 50 m, *Cáceres &*

Lücking 01-0600 (B-600124273, F), *01-0051* (B-600124275, F). Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (forest along main trail), 50 m, *M. Cáceres A05-046* (B, URM). PERNAMBUCO: Cabo de Santo Agostinho, Reserva Ecológica de Gurjaú, 8° 19' S, 35° 04' W, Mata Atlântica (closed forest), 30 m, *Cáceres & Lücking 00-0194* (B-600124054), *00-0193a* (F), *00-0196* (F, URM). Cabo de Santo Agostinho (Barragem), Reserva Ecológica de Gurjaú, 8° 19' S, 35° 04' W, Mata Atlântica (closed forest), 30 m, *Cáceres & Lücking 98-s.n.* (F). RIO GRANDE DO NORTE: Baía Formosa, Reserva Particular do Patrimônio Natural (RPPN) Mata Estrela Senador Antônio Farias, 06° 22' S, 35° 01' W, Mata Atlântica (closed forest), 0 m, *M. Cáceres 01-0163* (B-600124259, F, URM).

Lithothelium Müll. Arg. (Pyrenulaceae)

Notes. Lithothelium is a genus of relatively inconspicuous lichens differing from *Pyrenula* chiefly in that the endospore thickenings of the ascospores are found near the septa and edges only and ascospores are usually colorless (APTROOT 1991). *Lithothelium* thus can be confused with *Pseudopyrenula* and *Polymeridium* in the Trypetheliaceae but is distinguished from those genera by its unbranched paraphyses and ascus type.

Lithothelium spec.

Specimen examined. ALAGOAS: Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (forest along main trail), 50 m, *M. Cáceres A46-425* (F).

Lopezaria Kalb & Hafellner (incertae sedis)

Notes. Lopezaria resembles species of *Megalospora* but differs by its clear hymenium, among other characters including the ascus type (KALB 1990; RYAN & SIPMAN 2004). Similar species of *Catillaria* s.lat. and *Megalaria* have much smaller ascospores and 8-spored asci,

Lopezaria versicolor (Fée) Kalb & Haf. (FIG. 20C)

Specimen examined. PERNAMBUCO: Caruaru, Brejo dos Cavalos, 8° 20' S, 35° 58' W, Brejo de Altitude (high altitude rainforest), 800–900 m, *Cáceres & Lücking 00-0569* (B-600124055, F).

Malcolmiella Vězda (Pilocarpaceae)

Notes. Malcolmiella was originally established by VĚZDA (1997) for a new species from New Zealand, but it eventually became obvious that the new genus covered the whole of the *Lecidea piperis* group, that is the bulk of tropical corticolous species of *Lecidea* s.lat. with biatorine apothecia (LÜCKING & KALB 2000). *Malcolmiella* is one of the most speciose groups of tropical lichens and in need of a thorough revision. The genus is recog-

nized by its often conspicuous, brightly colored apothecia and thalli, non-septate ascospores, unbranched paraphyses and a *Byssoloma*-type ascus.

Key to species of *Malcolmiella*

1a. Excipulum with medullary layer throughout or in papillae 2
1b. Excipulum compact, lacking medullary layer 7

2a. Apothecial margin papillose 3
2b. Apothecial margin smooth 4

3a. Medulla pale cream-yellow, K+ orange ..... ***M.*** aff. ***granifera***
3b. Medulla white, K– ..... ***M.*** aff. ***psychotrioides***

4a. Medulla white, K– 5
4b. Medulla pale cream-yellow to yellow-orange, K+ orange to dark red. 6

5a. Apothecial disc orange-brown to red-brown ..... ***M. badimioides***
5b. Apothecial disc black-brown ..... ***M. psychotrioides***

6a. Medulla yellow-orange, K+ dark red; verrucae eventually breaking up into soralia ..... ***M. atlantica***
6b. Medulla pale cream-yellow, K+ orange; verrucae not breaking up into soralia ..... ***M. granifera***

7a. Hypothecium pale 8
7b. Hypothecium dark 11

8a. Medulla orange-red, K+ purple; apothecial disc grey-brown to black-brown; apothecial margin pale to dark brown ..... ***M.*** aff. ***piperis***
8b. Medulla white, K– 9

9a. Apothecial disc brown; apothecial margin pale to dark brown .... ***M. fuscella***
9b. Apothecial disc beige 10

10a. Apothecial margin pale, prominent when young ..... ***M. gyalectoides***
10b. Apothecial margin of same color as disc, not prominent . ***M. leptoloma***

11a. Medulla white, K– 12
11b. Medulla cream-yellow to orange-red, K+ orange or red-purple 17

12a. Thallus granulose-isidiate, green; apothecial disc beige, margin black; ascospores 11–15 × 5–8 µm ..... ***M. furfurosa***

12b. Thallus different; apothecial disc grey-brown to black-brown, margin pale to dark brown; ascospores mostly larger 13

13a. Thallus smooth to cracked..... 14
13b. Thallus sorediate to isidiate-sorediate 15

14a. Ascospores 20–25 × 10–14 µm ..... ***M. hypomela***
14b. Ascospores 13–17 × 7–9 µm ..... ***M. vinosa***

15a. Thallus isidiate-sorediate; ascospores 15–22 × 10–13 µm..... ..... ***M. perisidiata***
15b. Thallus sorediate; ascospores 15-17 × 8-10 µm or ascospores unknown 16

16a. Thallus grey-white; ascospores 15–17 × 8–10 µm..... ***M. polycampia***
16b. Thallus yellow-green; ascospores 10–13 × 5–7 µm .... ***M.*** aff. ***flavopustulosa***

17a. Thallus smooth to cracked; medulla orange-red, K+ purple ..***M. piperis***
17b. Thallus sorediate; medulla pale cream-yellow, K+ orange; ascospores 10–14 × 5–8 µm ..... ***M. flavopustulosa***

Malcolmiella atlantica Cáceres & Lücking **spec. nova** (FIG. 20E)

Malcolmiella granifera medulla flavo-aurantiaca K+ rubra et verrucis sorediiformibus differt. — Typus. SERGIPE: Areia Branca, Reserva Ecológica Serra de Itabaiana, 10° 45' S, 37° 20' W, Mata Atlântica (closed forest), 500 m, *Cáceres & Lücking 2209* (URM, holotypus; F, isotypus). — Paratypi. PERNAMBUCO: Bonito, Parque Municipal de Bonito, 8° 28' S, 35°43' W, Brejo de Altitude (high altitude rainforest), 800 m, *Cáceres & Lücking 00-0316* (F), *00-0317* (B). Caruaru, Brejo dos Cavalos, 8° 20' S, 35° 58' W, Brejo de Altitude (high altitude rainforest), 800–900 m, *Cáceres & Lücking 00-0545* (URM), *00-0598* (F), *00-0605* (F). SERGIPE: Santa Luzia, Private property, 11° 19' S, 37° 27' W, Mata Atlântica (closed forest), *Cáceres & Lücking 00-0868* (B), *00-0828* (F), *00-0849* (B, F), *00-0861* (B, F), *00-0869* (F), *00-0853* (URM).

Description. Thallus crustose, corticolous, continuous, 20–50 mm across and 50–250 µm thick, densely verrucose but verrucae eventually breaking up to produce soralia, green-grey with patches of bright yellow-orange, K+ blood-red pigment where medulla is exposed or verrucae are eroded or break up into soralia; soralia rounded to slightly irregular, farinose, bright yellow-orange, K+ blood-red. Photobiont chlorococcoid; cells 4–7 µm diam. Apothecia sessile, rounded to crenulate, 0.5–2 mm diam. and 250–350 µm high; disc plane to slightly convex, dark grey-brown; margin thick, slightly prominent, cream-colored to pale yellow. Excipulum externally prosoplectenchymatous with anticlinally arranged hyphae and loose hyphal

ends, 10–20 µm broad, hyaline at periphery but with grey-brown subperipheral layer, internally with medullary layer composed of loosely arranged, periclinal hyphae with constricted septa, 50–100 µm broad, incrusted with ochraceous-yellow hydrophobic granules, nubilous but dissolving in KOH with K+ red to pink-red reaction. Hypothecium 30–70 µm high, blackish brown, K–. Epithecium indistinct. Hymenium 70–90 µm high, colorless. Asci 60–80 × 10–12 µm. Ascospores 8 per ascus, non-septate, ellipsoid, 10–16 × 6–8 µm, 1.8–2 times as long as broad. Pycnidia not observed. Chemistry: unidentified anthraquinone.

Notes. *Malcolmiella atlantica* combines features of the *M. granifera* and the *M. amazonica* group. As in the first, the apothecia have a medullary excipulum incrusted with crystals, although in other species of the *M. granifera* group, these crystals are colorless to at best pale yellow (in *M. granifera*) and react K– or K+ yellow to orange but not red or pink. The verrucose thallus with the bright yellow-orange, K+ red crystals (which are the same as in the excipulum) closely resembles that of *M. amazonica*, which has the same pigment in the medulla of its verrucae. However, *M. amazonica* differs in several aspects from *M. atlantica*: except for the content of the verrucae, the thallus medulla contains an orange-red, K+ purple pigment different from that of the verrucae, the verrucae do not break up into soralia, the excipulum lack a medullary tissue, and the apothecial margin contains the same orange-red, K+ purple pigment as the thallus medulla but not the verrucae. Otherwise, the two species look similar and also have the same ascospore dimensions. While *M. amazonica* is a widespread neotropical species, *M. atlantica* has so far only been found in the Atlantic rainforest, and the numerous collections available suggest that it is a true endemic of that region.

Malcolmiella badimioides Cáceres & Lücking **spec. nova** (FIG. 20F)

Malcolmiella psychotrioides discis apotheciorum aurantiacis et hypothecio pallido differt. — Typus. PERNAMBUCO: Cabo de Santo Agostinho, Reserva Ecológica de Gurjaú, 8° 19' S, 35° 04' W, Mata Atlântica (closed forest), 30 m, *Cáceres & Lücking 00-0212* (F, holotypus; B, isotypus). — Paratypi. ALAGOAS: Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (closed forest), 50 m, *Cáceres & Lücking 00-0692* (B). Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (forest along main trail), 50 m, *M. Cáceres A05-043a* (F), *A33-255* (B, URM). PERNAMBUCO: Cabo de Santo Agostinho, Reserva Ecológica de Gurjaú, 8° 19' S, 35° 04' W, Mata Atlântica (closed forest), 30 m, *Cáceres & Lücking 00-0198b* (F), *00-0205b* (F), *00-0213* (F), *00-0219* (F), *00-0215* (URM). Igarassu, Refúgio Ecológico Charles Darwin, 7° 50' S, 34° 54' W, Mata Atlântica (closed forest), 20 m, *Cáceres & Lücking 00-0474a* (B), *00-0475* (B, F, URM), *00-0476* (F), *00-0479a* (F), *00-0473* (URM), *00-0477* (URM), *00-0478* (URM). São Lourenço da Mata, Estação Ecológica de Tapacurá, 8° 02' S, 35° 09' W, Agreste (open dry forest), 100 m, *Cáceres & Lücking 98-0512* (URM). Rio Grande do Norte: Baía Formosa, Reserva

Particular do Patrimônio Natural (RPPN) Mata Estrela Senador Antônio Farias, 06° 22' S, 35° 01' W, Mata Atlântica (closed forest), 0 m, *M. Cáceres 01-0181* (B), *01-0159* (F), *01-0180* (URM). SERGIPE: Areia Branca, Reserva Ecológica Serra de Itabaiana, 10° 45' S, 37° 20' W, Mata Atlântica (closed forest), 500 m, *Cáceres & Lücking 2212* (B), *2200* (F), *2208* (F, URM), *2213* (F), *2214* (F), *2211* (URM). Santa Luzia, Private property, 11° 19' S, 37° 27' W, Mata Atlântica (closed forest), *Cáceres & Lücking 00-0839* (URM).

Description. Thallus crustose, corticolous, continuous, 20–50 mm across and 30–70 μm thick, densely verrucose, green-grey; medulla white, K–. Photobiont chlorococcoid; cells 4–7 μm diam. Apothecia sessile, rounded, 0.4–0.8 mm diam. and 250–350 μm high; disc plane, orange-brown to brown-red; margin thick, slightly prominent, cream-colored to white. Excipulum externally paraplectenchymatous with small cells and loose hyphal ends, 20–50 μm broad, hyaline, internally with medullary layer composed of loosely arranged, periclinal hyphae with constricted septa, 40–60 μm broad, incrusted with hydrophobic granules, nubilous but dissolving in KOH with K+ grass-green reaction. Hypothecium 20–30 μm high, orange-brown, K–. Epithecium indistinct. Hymenium 80–100 μm high, colorless. Asci 70–90 × 15–20 μm. Ascospores 8 per ascus, non-septate, ellipsoid, 15–20 × 6–10 μm, 2–2.5 times as long as broad. Pycnidia not observed. Chemistry: no substances detected by TLC.

Notes. This new species is characterized by its orange brown to brownish red apothecia with thick, chamois-colored margin, which closely resemble the apothecia of *Badimia dimidiata* and related species. A microscopical examination, however, reveals the fundamental differences between those two genera. The new species belongs to the *Malcolmiella granifera* group, which is characterized by its well-developed, K+ yellow to green medullary tissue in the excipulum. Within this group, *M. badimioides* is distinguished by its colourless medulla and its rather light colored apothecia with light colored hypothecium.

Malcolmiella flavopustulosa Cáceres & Lücking **spec. nova** (FIG. 20G)

Malcolmiella granifera verrucis sorediformibus et excipulo compacto differt. — Typus. ALAGOAS: Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (closed forest), 50 m, *M. Cáceres 2011* (F, holotype; URM, isotype). — Paratype. PERNAMBUCO: Igarassu, Refúgio Ecológico Charles Darwin, 7° 50' S, 34° 54' W, Mata Atlântica (closed forest), 20 m, *Cáceres & Lücking 00-0390* (F).

Description. Thallus crustose, corticolous, continuous, 20–50 mm across and 50–150 μm thick, densely pustulose-verrucose but verrucae soon breaking up to produce irregular to partly confluent, coarse soralia, green-grey but content of pustules pale yellow, K+ dark yellow to orange; soralia rounded to irregular and partly confluent, granulose, sometimes developing

into coralloid, isidia-like structure, their contents pale yellow, K+ dark yellow to orange. Photobiont chlorococcoid; cells 4–7 μm diam. Apothecia sessile, rounded to irregular, 0.5–1.5 mm diam. and 250–350 μm high; disc plane to convex, brown; margin thin but distinct, not or slightly prominent, pale grey. Excipulum prosoplectenchymatous, 30–50 μm broad, hyaline but inner parts sordid yellow, incrusted with yellow hydrophobic granules, K+ deep yellow, then orange. Hypothecium 30–50 μm high, blackish brown, K–. Epithecium indistinct. Hymenium 70–90 μm high, colorless. Asci 60–80 × 10–13 μm. Ascospores 8 per ascus, non-septate, ellipsoid, 10–14 × 5–8 μm, 1.8–2 times as long as broad. Pycnidia not observed. Chemistry: unknown anthraquinone.

Notes. This taxon is known from two collections, one sterile and one with apothecia. The pigment is identical with that found in *M. granifera*, but that species has a more irregularly verrucose thallus which exposes the pigment only in eroded verrucae and the verrucae never break up to form soralia or coralloid isidia-like structures. In addition, *M. granifera* has a medullary excipulum. The only genuinely sorediate species in the genus known so far are *M. polycampia*, which looks similar to *M. flavopustulata* but has white soralia lacking pigment, and *M. ceylandica*, with medullary excipulum and extensive farinose soralia.

Malcolmiella aff. ***flavopustulosa*** Cáceres & Lücking

Notes. The material is similar to the preceeding species in producing a yellow-green, sorediate thallus. However, the medulla is white instead of pale yellow, and the ascospores are smaller. Only one thallus had apothecia, so the differences cannot be evaluated with certainty at this point.

Specimens examined. ALAGOAS: Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (forest along main trail), 50 m, *Cáceres A07-058* (URM), *A11-113* (F), *A12-120a* (F), *A17-157* (URM), *A17-171* (URM), *A19-179* (URM), *A24-202* (B), *A24-208* (URM), *A25-219* (B), *A41-324* (B), *A42-324a* (F), *A45-368* (URM), *A46-426a* (F), *A46-434* (F), *A47-445a* (F).

Malcolmiella furfurosa (Tuck. ex Nyl.) Cáceres & Lücking **comb. nova** (FIG. 20G)

Lecidea furfurosa Tuck. ex Nyl., Ann. Sci. Nat., Bot., sér. 4, 19: 341, not. (1863).

Specimens examined. PERNAMBUCO: Igarassu, Refúgio Ecológico Charles Darwin, 7° 50' S, 34° 54' W, Mata Atlântica (closed forest), 20 m, *Cáceres & Lücking 00-0462* (B, F, URM). SERGIPE: Areia Branca, Reserva Ecológica Serra de Itabaiana, 10° 45' S, 37° 20' W, Mata Atlântica (closed forest), 500 m, *Cáceres & Lücking 2197* (B, F, URM). Santa Luzia, Private property, 11° 19' S, 37° 27' W, Mata Atlântica (closed forest), *Cáceres & Lücking 00-0825* (F).

Malcolmiella fuscella (Müll. Arg.) Cáceres & Lücking **comb. nova** (FIG. 21A)

Lecidea fuscella Müll. Arg., Flora 33: 14. (1881).

Specimens examined. ALAGOAS: Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (closed forest), 50 m, *Cáceres & Lücking 01-0031* (F). PERNAMBUCO: Caruaru, Brejo dos Cavalos, 8° 20' S, 35° 58' W, Brejo de Altitude (high altitude rainforest), 800–900 m, *Cáceres & Lücking 00-0591* (B), *00-0674* (B), *00-0582c* (F), *00-0592* (B, F), *00-0672* (URM), *00-0673* (F), *00-0675* (F), *00-0679* (B, F), *00-0680* (F), *00-0687* (F), *00-0579* (URM), *00-0593* (URM). Caruaru, Instituto Pernambucano de Pesquisas Agropecuárias (IPA), 8° 17' S, 35° 58' W, Caatinga (open thornbush), 500–600 m, *Cáceres & Lücking 00-0106* (B, F), *00-0107* (F, URM), *00-0108a* (F), *00-0109* (URM).

Malcolmiella granifera (Ach.) Kalb & Lücking (FIG. 21B)

Specimens examined. PERNAMBUCO: São Lourenço da Mata, Estação Ecológica de Tapacurá, 8° 02' S, 35° 09' W, Agreste (open dry forest), 100 m, *Cáceres & Lücking 98-0260* (F). RIO GRANDE DO NORTE: Baía Formosa, Reserva Particular do Patrimônio Natural (RPPN) Mata Estrela Senador Antônio Farias, 06° 22' S, 35° 01' W, Mata Atlântica (closed forest), 0 m, *M. Cáceres 01-0172* (F). SERGIPE: Areia Branca, Reserva Ecológica Serra de Itabaiana, 10° 45' S, 37° 20' W, Mata Atlântica (closed forest), 500 m, *Cáceres & Lücking 2190* (B, F), *2215* (F), *2190* (URM). Ribeira, Mata Atlântica, *M. Cáceres 2032* (B, F, URM).

Malcolmiella aff. ***granifera*** (Ach.) Kalb & Lücking

Notes. *Malcolmiella* aff. *granifera* is characterized by the strongly crenulate apothecial margin, caused by the medullary excipulum forming chambers. This taxon is probably undescribed but more type material of tropical *Lecidea* species needs to be examined.

Specimens examined. ALAGOAS: Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (closed forest), 50 m, *Cáceres & Lücking 01-0556* (B), *01-0557* (B), *01-0074* (B-600124184), *01-0059* (F), *01-0069* (F), *01-0072* (F), *01-0073* (F), *01-0100* (F), *01-0541a* (F), *01-0082* (URM), *01-0099* (URM), *2000* (URM). PERNAMBUCO: Bonito, Parque Municipal de Bonito, 8° 28' S, 35°43' W, Brejo de Altitude (high altitude rainforest), 800 m, *Cáceres & Lücking 00-0331* (F). Cabo de Santo Agostinho, Reserva Ecológica de Gurjaú, 8° 19' S, 35° 04' W, Mata Atlântica (closed forest), 30 m, *Cáceres & Lücking 00-0207* (B-600124151), *00-0209* (B-600124152), *00-0211* (B-600124153), *00-0205a* (F), *00-0208* (F), *00-0209* (F), *00-0211* (F), *00-0210* (URM).

Malcolmiella gyalectoides (Vain.) Cáceres & Lücking **comb. nova** (FIG. 21C)

Lecidea gyalectoides Vain., in: HIERN W. P. (edit.): Catalogue of the African plants collected by Dr. Friedrich Welwitsch in 1853 – 61, vol. II(2): 423 (1901).

Specimens examined. ALAGOAS: Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (closed forest), 50 m, *Cáceres 2068* (F). Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (forest along main trail), 50 m, *M. Cáceres A41-320a* (F). PERNAMBUCO: Bonito, Parque Municipal de Bonito, 8° 28' S, 35°43' W, Brejo de Altitude (high altitude rainforest), 800 m, *Cáceres & Lücking 00-0344* (B), *00-0342* (URM). Cabo de Santo Agostinho, Reserva Ecológica de Gurjaú, 8° 19' S, 35° 04' W, Mata Atlântica (closed forest), 30 m, *Cáceres & Lücking 00-0199* (F). Caruaru, Brejo dos Cavalos, 8° 20' S, 35° 58' W, Brejo de Altitude (high altitude rainforest), 800–900 m, *Cáceres & Lücking 00-0682* (F, URM). Caruaru, Instituto Pernambucano de Pesquisas Agropecuárias (IPA), 8° 17' S, 35° 58' W, Caatinga (open thornbush), 500–600 m, *Cáceres & Lücking 00-0078* (B, F, URM). SERGIPE: Areia Branca, Reserva Ecológica Serra de Itabaiana, 10° 45' S, 37° 20' W, Mata Atlântica (closed forest), 500 m, *Cáceres & Lücking 2210* (F).

Malcolmiella hypomela (Nyl.) Cáceres & Lücking **comb. nova** (FIG. 21D)

Lecidea hypomela Nyl., Ann. Sci. Nat., Bot., sér. 4, 11: 223 (1859).

Specimens examined. PERNAMBUCO: Bonito, Parque Municipal de Bonito, 8° 28' S, 35°43' W, Brejo de Altitude (high altitude rainforest), 800 m, *Cáceres & Lücking 00-0345* (B-600124105), *00-0347* (B-600124106), *00-0346* (URM). Caruaru, Brejo dos Cavalos, 8° 20' S, 35° 58' W, Brejo de Altitude (high altitude rainforest), 800–900 m, *Cáceres & Lücking 00-0580* (B-600124107, F, URM), *00-0686* (B-600124108), *00-0582a* (F), *00-0587* (F), *00-0685* (F), *00-0688* (F), *00-0689* (F), *00-0590* (URM).

Malcolmiella leptoloma (Müll. Arg.) Cáceres & Lücking **comb. nova** (FIG. 21E)

Lecidea leptoloma Müll. Arg., *Flora* **64:** 518. 1881.

Specimens examined. ALAGOAS: Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (forest along main trail), 50 m, *M. Cáceres A35-274c* (F). PERNAMBUCO: Bonito, Parque Municipal de Bonito, 8° 28' S, 35°43' W, Brejo de Altitude (high altitude rainforest), 800 m, *Cáceres & Lücking 00-0334* (URM). Cabo de Santo Agostinho, Reserva Ecológica de Gurjaú, 8° 19' S, 35° 04' W, Mata Atlântica (closed forest), 30 m, *Cáceres & Lücking 00-0201* (B, F, URM), *00-0202* (F), *00-0204* (URM). Caruaru, Brejo dos Cavalos, 8° 20' S, 35° 58' W, Brejo de Altitude (high altitude rainforest), 800–900 m, *Cáceres & Lücking 00-0576* (B, F), *00-0683* (B), *00-0577* (F), *00-0578* (F), *00-0664a* (F), *00-0681* (F), *00-0684* (F, URM). Caruaru, Instituto Pernambucano de Pesquisas Agropecuárias (IPA), 8° 17' S, 35° 58' W, Caatinga (open thornbush), 500–600 m, *Cáceres & Lücking 00-0079* (B, F). SERGIPE: Ribeira, Mata Atlântica, *M. Cáceres 2043* (F).

Malcolmiella perisidiata (Malme) Cáceres & Lücking **comb. et stat. nova**

Lecidea piperis var. *perisidiata* Malme, Ark. Bot. 28A (7): 24 (1936).

Specimens examined. ALAGOAS: Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (forest along main trail), 50 m, *M. Cáceres A01-007a* (F).

Malcolmiella piperis (Spreng.) Kalb & Lücking (FIG. 21F)

Specimens examined. ALAGOAS: Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (closed forest), 50 m, *Cáceres & Lücking 01-0500* (B, F), *2008* (F, URM), *s.n.* (F), *s.n.* (F), *01-0080* (URM), *01-0118* (URM), *01-0577* (URM). Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (forest along main trail), 50 m, *M. Cáceres A05-042* (F, URM), *A05-043b* (F), *A09-077* (URM), *A09-084b* (B, F), *A09-090a* (F), *A17-151c* (F), *A17-159b* (URM), *A18-166* (B, URM), *A18-170a* (F), *A21-183* (URM), *A21-184c* (B), *A24-201* (B, URM), *A26-227* (URM), *A40-315* (F), *A41-315* (F), *A41-319a* (F), *A42-315* (F), *A42-324b* (F), *A46-416a* (F). PERNAMBUCO: Cabo de Santo Agostinho, Reserva Ecológica de Gurjaú, 8° 19' S, 35° 04' W, Mata Atlântica (closed forest), 30 m, *Cáceres & Lücking 00-0191* (F), *00-0198a* (F), *00-0200* (F). Caruaru, Brejo dos Cavalos, 8° 20' S, 35° 58' W, Brejo de Altitude (high altitude rainforest), 800–900 m, *Cáceres & Lücking 00-0678* (B-600124085), *00-0588* (B-600124086, F, URM), *00-0586* (B-600124087), *00-0581* (hb. Kalb), *00-0589* (F), *00-0677* (F), *00-0690* (F), *00-0583* (URM). São Lourenço da Mata, Estação Ecológica de Tapacurá, 8° 02' S, 35° 09' W, Agreste (open dry forest), 100 m, *Cáceres & Lücking 98-0251* (URM). RIO GRANDE DO NORTE: Baía Formosa, Reserva Particular do Patrimônio Natural (RPPN) Mata Estrela Senador Antônio Farias, 06° 22' S, 35° 01' W, Mata Atlântica (closed forest), 0 m, *M. Cáceres 01-0186* (B, F, URM), *01-0190* (URM). SERGIPE: Itabaiana, Fazenda São Jose, 10° 45' S, 37° 20' W, Mata Atlântica (closed forest), 500 m, *M. Cáceres 2033* (F). Ribeira, Mata Atlântica, *M. Cáceres 2051* (F, URM).

Malcolmiella aff. ***piperis*** (Spreng.) Kalb & Lücking

Notes. This probably undescribed species agrees in all features with *Malcolmiella piperis*, except for the pale instead of dark brown hypothecium, which theoretically puts it in a different subgroup but illustrates the close relationship of species with pale and dark brown hypothecium.

Specimens examined. ALAGOAS: Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (forest along main trail), 50 m, *M. Cáceres A06-047* (F), *A35-274* (B, F). PERNAMBUCO: Igarassu, Refúgio Ecológico Charles Darwin, 7° 50' S, 34° 54' W, Mata Atlântica (closed forest), 20 m, *Cáceres & Lücking 00-0458* (F).

Malcolmiella polycampia (Tuck.) Cáceres & Lücking **comb. nova** (FIG. 21G)

Lecidea polycampia Tuck., Proc. Amer. Acad. Arts and Sci. 6: 274 (1864).

Specimens examined. ALAGOAS: Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (forest along main trail), 50 m, *M. Cáceres A01-015* (F), *A09-072* (F), *A09-092* (B), *A11-110* (F), *A18-162* (URM), *A18-168* (F), *A46-427b* (URM), *A47-445b* (F).

Malcolmiella psychotrioides Kalb & Lücking (FIG. 21H)

Specimens examined. ALAGOAS: Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (closed forest), 50 m, *M. Cáceres s.n.* (URM). Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (forest along main trail), 50 m, *M. Cáceres A42-324c* (F). PERNAMBUCO: Cabo de Santo Agostinho, Reserva Ecológica de Gurjaú, 8° 19' S, 35° 04' W, Mata Atlântica (closed forest), 30 m, *Cáceres & Lücking 00-0216* (B), *00-0205c* (F), *00-0214* (B, F), *00-0217* (F), *00-0218* (F), *00-0220a* (F). Igarassu, Refúgio Ecológico Charles Darwin, 7° 50' S, 34° 54' W, Mata Atlântica (closed forest), 20 m, *Cáceres & Lücking 00-0466* (B), *00-0470* (B), *00-0474b* (B), *00-0459a* (F), *00-0463* (F, URM), *00-0467* (F), *00-0469* (F), *00-0479b* (F), *00-0464* (URM), *00-0465* (URM), *00-0468* (URM), *00-0471* (URM), *00-0472* (URM). Recife, Dois Irmãos, Mata Atlântica (closed forest), *Cáceres & Lücking 98-0520* (URM), *99-0507* (URM). São Lourenço da Mata, Estação Ecológica de Tapacurá, 8° 02' S, 35° 09' W, Agreste (open dry forest), 100 m, *Cáceres & Lücking 98-0511* (B, F, URM). RIO GRANDE DO NORTE: Baía Formosa, Reserva Particular do Patrimônio Natural (RPPN) Mata Estrela Senador Antônio Farias, 06° 22' S, 35° 01' W, Mata Atlântica (closed forest), 0 m, *M. Cáceres 01-0172* (B). SERGIPE: Areia Branca, Reserva Ecológica Serra de Itabaiana, 10° 45' S, 37° 20' W, Mata Atlântica (closed forest), 500 m, *Cáceres & Lücking 2215* (F).

Malcolmiella aff. ***psychotrioides*** Kalb & Lücking (FIG. 20D)

Notes. This material agrees in all aspects with *Malcolmiella psychotrioides* but differs in its crenulate apothecial margin, the same way as *M.* aff. *granifera* differs from *M. granifera*.

Specimens examined. ALAGOAS: Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (forest along main trail), 50 m, *M. Cáceres A16-149* (URM), *A41-322* (F), *A42-322* (F).

Malcolmiella vinosa (Eschw.) Kalb & Lücking

Specimens examined. ALAGOAS: Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (closed forest), 50 m, *Cáceres & Lücking 01-0096* (B, F), *01-0543* (F), *01-0081* (URM), *01-0097* (URM), *01-0500* (URM), *01-0559* (URM). Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (forest along main trail), 50 m, *M. Cáceres A33-254a* (URM), *A41-321b* (F). PERNAMBUCO: Cabo de Santo Agostinho, Reserva Ecológica de Gurjaú, 8° 19' S, 35° 04' W, Mata Atlântica (closed forest), 30 m, *Cáceres & Lücking 00-0190* (B-600124154, F), *00-0191a* (F). Caruaru, Brejo dos Cavalos, 8° 20' S, 35° 58' W, Brejo de Altitude (high altitude rainforest), 800–900 m, *Cáceres & Lücking 00-0582b* (F), *00-0664d* (F). RIO GRANDE DO NORTE: Baía Formosa, Reserva Particular do Patrimônio Natural (RPPN) Mata Estrela Senador Antônio Farias, 06° 22' S, 35° 01' W, Mata Atlântica (closed forest), 0 m, *M. Cáceres 01-0184* (F). SERGIPE: Itabi, Private property, 10° 06' S, 37° 54' W, Caatinga (thornbush), 100 m, *M. Cáceres 2187* (F). Ribeira, Mata Atlântica, *M. Cáceres 2040a* (B), *2034* (F), *2035* (F), *2036* (F), *2039* (F, URM), *2040a* (F, URM), *2041* (F, URM), *2050* (F, URM), *2067* (F), *2068* (F).

Maronina Hafellner & R. W. Rogers (Lecanoraceae)

Notes. Maronina closely resembles species of *Lecanora* but differs chiefly by its polyspored asci and small ascospores (HAFELLNER & ROGERS 1990; MCCARTHY 2004). The genus is typical of more arid climates.

Maronina multifera (Nyl.) Hafellner & R. W. Rogers (FIG. 22A)

Specimens examined. PERNAMBUCO: Caruaru, Brejo dos Cavalos, 8° 20' S, 35° 58' W, Brejo de Altitude (high altitude rainforest), 800–900 m, *Cáceres & Lücking 00-0658* (B-600124100, duplicate, F, URM), *00-0805c* (B-600124145), *00-0659* (F). Caruaru, Instituto Pernambucano de Pesquisas Agropecuárias (IPA), 8° 17' S, 35° 58' W, Caatinga (open thornbush), 500–600 m, *Cáceres & Lücking 00-0064* (B-600124056, F), *00-0058b* (F), *00-0061* (F), *00-0062* (F), *00-0060* (URM), *00-0063* (URM), *00-0123* (URM). SERGIPE: Gararu, 9° 58' S, 37° 54' W, Caatinga (thornbush), 0–100 m, *M. Cáceres 2122* (F, URM).

Mazosia A. Massal. (Roccellaceae)

Notes. Mazosia is a genus of chiefly foliicolous lichens but is also found on smooth bark, stilt roots of palms and other suitable substrata (KALB & VĚZDA 1988; HARRIS 1995; LÜCKING & MATZER 1996). Corticolous specimens are usually identified as *M. ocellata*, but there might be more species involved in this complex.

Key to species of *Mazosia*

1a. Thallus smooth ..... ***M. ocellata***
1b. Thallus irregularly verruculose..... ***M phyllosema***

Mazosia ocellata (Nyl.) R. C. Harris (FIG. 22B)

Specimens examined. ALAGOAS: Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (closed forest), 50 m, *M. Cáceres 2000* (B), *Cáceres & Lücking 01-0157b* (F), *Cáceres 2013* (F), *2014* (URM). Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (forest along main trail), 50 m, *M. Cáceres A08-061* (F), *A21-187* (F, URM), *A38-cortex* (F), *A45-366a* (F), *A45-367a* (F). PERNAMBUCO: Bonito, Parque Municipal de Bonito, 8° 28' S, 35°43' W, Brejo de Altitude (high altitude rainforest), 800 m, *Cáceres & Lücking 00-0332* (F). Igarassu, Refúgio Ecológico Charles Darwin, 7° 50' S, 34° 54' W, Mata Atlântica (closed forest), 20 m, *Cáceres & Lücking 00-0400* (B), *00-0413* (F), *00-0389* (URM), *00-0420* (URM). RIO GRANDE DO NORTE: Baía Formosa, Reserva Particular do Patrimônio Natural (RPPN) Mata Estrela Senador Antônio Farias, 06° 22' S, 35° 01' W, Mata Atlântica (closed forest), 0 m, *M. Cáceres 01-0170* (B).

Mazosia phyllosema (Nyl.) Zahlbr.

Specimen examined. SERGIPE: Ribeira, Mata Atlântica, *M. Cáceres 2040b* (F).

Megalotremis Aptroot (Monoblastiaceae)

Notes. Megalotremis is a typical member of Monoblastiaceae and somewhat intermediate between *Anisomeridium*, with which it shares the pycnidial conidiomata, and *Musaespora*, which has similarly large ascospores (APTROOT 1991; HARRIS 1995). The present material was found without ascomata, but the conidiomata are similar to a species recently found in Costa Rica (LÜCKING, pers. comm. 2006).

Megalotremis spec.

Specimens examined. PERNAMBUCO: Bonito, Parque Municipal de Bonito, 8° 28' S, 35°43' W, Brejo de Altitude (high altitude rainforest), 800 m, *Cáceres & Lücking 00-0287* (F), *00-0305* (F).

Musaespora Aptroot & Sipman (Monoblastiaceae)

Notes. APTROOT & SIPMAN (1993) established this new genus to accommodate several new species of pyrenocarpous lichens with campylidioid anamorph. Originally assigned to Aspidotheliaceae (= Thelenellaceae), the genus was later included in Monoblastiaceae and is indeed closely related to *Anisomeridium* and *Megalotremis* (HARRIS 1995; LÜCKING & SÉRUSIAUX 1996).

Key to species of *Musaespora*

1a. Perithecia solitary ..... ***M. kalbii***
1b. Perithecia aggregate in stromatic warts 2

2a. Aggregate perithecia with fused ostiole ..... ***M. epiphylla***
2b. Aggregate perithecia with separate ostioles ..... ***M. gigas***

Musaespora epiphylla (R. Sant.) R. C. Harris (FIG. 22C)

Specimen examined. PERNAMBUCO: Bonito, Parque Municipal de Bonito, 8° 28' S, 35°43' W, Brejo de Altitude (high altitude rainforest), 800 m, *Cáceres & Lücking 00-0309* (F).

Musaespora gigas (Zahlbr.) R. C. Harris

Specimen examined. SERGIPE: Areia Branca, Reserva Ecológica Serra de Itabaiana, 10° 45' S, 37° 20' W, Mata Atlântica (closed forest), 500 m, *M. Cáceres 2082* (B, F, URM).

Musaespora kalbii Lücking & Sérus. (FIG. 22D)

Specimen examined. PERNAMBUCO: Cabo de Santo Agostinho, Reserva Ecológica de Gurjaú, 8° 19' S, 35° 04' W, Mata Atlântica (closed forest), 30 m, *Cáceres & Lücking 00-0145* (B-600124210, URM).

Mycomicrothelia Keissler (Arthopyreniaceae)

Notes. Mycomicrothelia is a genus of inconspicuous lichens similar to *Arthopyrenia* but with brown, usually ornamented ascospores (HAWKSWORTH 1985; APTROOT 1991; HARRIS 1995). The present, sparse material has a UV+ yellow thallus and seems to contain lichexanthone, a feature thus far not known from the genus.

Mycomicrothelia hemispherica (Müll. Arg.) D. Hawksw.

Specimen examined. SERGIPE: Itabi, Private property, 10° 06' S, 37° 54' W, Caatinga (thornbush), 100 m, *M. Cáceres 2160* (F).

Myeloconis P.M. McCarthy & Elix (Myeloconidiaceae)

Notes. Myeloconis is a small genus of tropical, pyrenocarpous lichens with features somewhat intermediate between Porinaceae in the Ostropomycetidae and Trypetheliaceae in the Dothideomycetidae (MCCARTHY & ELIX 1996; MCCARTHY 2001). The species are often sterile but usually feature the typical, brightly colored soralia.

Myeloconis guyanensis P. M. McCarthy & Elix (FIG. 22E)

Specimen examined. PERNAMBUCO: Bonito, Parque Municipal de Bonito, 8° 28' S, 35°43' W, Brejo de Altitude (high altitude rainforest), 800 m, *Cáceres & Lücking 00-0324* (B, F).

Myriotrema Fée (Thelotremataceae)

Notes. In the frame of an extensive generic rearrangement of the family Thelotremataceae, the genus *Myriotrema* was redefined to include species with colorless excipulum lacking periphysoids and lack of a periderm layer in the thalline apothecial margin (FRISCH 2006). This definition agrees in many aspects with that of HALE (1980), although many species included in that genus by HALE are now placed in different genera (FRISCH 2006; FRISCH & KALB 2006). Many species of *Myriotrema* s.str. are characterized by small, immersed apothecia with pore-like opening, but such apothecia are also found outside the genus, e.g. in *Thelotrema glaucopallens*.

Key to species of *Myriotrema*

1a. Soralia present; apothecia absent.....***M.*** spec.

1b. Soralia absent; apothecia present..... 2

2a. Ascospores submuriform, 12–14 × 6–10 µm; apothecia immersed, 0.2 mm in diam.; pore size 0.1 mm ..... ***M. myrioporoides***
2b. Ascospores transversely septate; apothecia erumpent; pore size 0.1–0.2 mm..... 3

3a. Ascospores 3-septate, 18 × 8 µm; apothecia 0.2–0.4 mm in diam.; hypoprotocetraric acid..... ***M. congestum***
3b. Ascospores 3–5-septate; apothecia 0.5–1 mm in diam.; psoromic acid. 4

4a. Ascospores 12–16 × 5–6 µm; columella absent; excipulum free, forming a double margin..... ***M. costaricense***
4b. Ascospores 12–24 × 5–8 µm; columella reticulate; excipulum free..... ..... ***M. glaucophaenum***

Myriotrema congestum (Hale) Hale (FIG. 22F)

Specimens examined. ALAGOAS: Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (forest along main trail), 50 m, *M. Cáceres A08-070* (F), *A46-419a* (F), *A46-428* (F).

Myriotrema costaricense (Müll. Arg.) Hale

Specimens examined. ALAGOAS: Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (closed forest), 50 m, *M. Cáceres s.n.* (F). Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (forest along main trail), 50 m, *M. Cáceres A01-005* (F), *A01-012* (F), *A06-050a* (F), *A08-065* (F), *A38-289* (F), *A40-305* (F), *A45-366* (F).

Myriotrema glaucophaenum (Kremp.) Hale (FIG. 22G)

Specimen examined. SERGIPE: Santa Luzia, Private property, 11° 19' S, 37° 27' W, Mata Atlântica (closed forest), *Cáceres & Lücking 00-0902* (B, F, URM), *00-0903* (B, F, URM).

Myriotrema myrioporoides (Müll. Arg.) Hale (FIG. 22H)

Specimens examined. ALAGOAS: Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (closed forest), 50 m, *Cáceres & Lücking 01-0576* (F, URM). Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (forest along main trail), 50 m, *M. Cáceres A23-194* (F).

Myriotrema spec.

Specimens examined. ALAGOAS: Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (forest along main trail), 50 m, *M. Cáceres A01-004* (F), *A06-050c* (F).

Ocellularia G. Mey. (Thelotremataceae)

Notes. In the generic redisposition of the Thelotremataceae (FRISCH 2006; FRISCH & KALB 2006; FRISCH *et al.* 2006), *Ocellularia* s.str. is defined as having a brown to carbonized excipulum lacking periphysoids, a carbonized columella, and a periderm layer as part of the thalline apothecial margin. However, the residual *Ocellularia* is still highly variable and needs further study. The present species belong to either *Ocellularia* s.str. or the *Ocellularia interpositum* group; *O. bahiana* differs by its colorless excipulum.

Key to species of *Ocellularia*

1a. Soralia present; apothecia absent 2
1b. Soralia absent; apothecia present 4

2a. Norstictic acid present; soralia pink-red ..... ***O.*** spec. A
2b. No substances; soralia white-green or yellow-green 3

3a. Soralia yellow-green ..... ***O.*** spec. B
3b. Soralia white-green ..... ***O.*** spec. C

4a. Ascospores transversely septate 5
4b. Ascospores submuriform to muriform 11

5a. Medulla with yellow or orange-red pigment 6
5b. Medulla not pigmented 8

6a. Ascospores 5–7-septate, 18–22 × 5–8 µm; apothecia erumpent; columella absent; medulla orange-red ..... ***O. crocea***
6b. Ascospores 7–23-septate; apothecia prominent; columella present; medulla orange-red or yellow 7

7a. Ascospores 7–17-septate, 30–70 × 6–12 µm; apothecia 0.6–0.9 mm in diam.; medulla yellow; cinchonarum unknown ..... ***O. cavata***
7b. Ascospores 15–23-septate, 80–150 × 15–20 µm; apothecia 0.5–0.7 mm in diam.; medulla orange-red; no substances ..... ***O. gracilis***

8a. Ascospores 5–7-septate, 20–30 × 6–10 µm; apothecia 0.3–0.6 mm in diam.; pore size 0.1–0.2 mm ..... ***O. papillata***
8b. Ascospores 3–5-septate; apothecia and pore larger than above **9**

9a. Ascospores 19–25 × 7–9 µm; protocetraric acid; apothecia 0.5–1.5 mm in diam.; columella present to reticulate ..... ***O. mauritiana***
9b. Ascospores smaller; cinchonarum unknown or no substances; apothecia 0.4–1.0 mm in diam.; columella present **10**

10a. Ascospores 12–15 × 5–6 µm; cinchonarum unknown; apothecia 0.4–0.7 mm in diam. ..... ***O. subemersa***
10b. Ascospores 14–19 × 5–6 µm; no substances; apothecia 0.7–1.0 mm in diam. ..... ***O. landronii***

11a. Ascospores submuriform, brown, 16–24 × 12–14 µm; apothecia erumpent, 0.4-0.8 mm in diam.; columella absent; protocetraric acid ... . ***O. bahiana***
11b. Ascospores muriform, colorless, 100–250 × 25–45 µm; apothecia prominent, 1.0-2.0 mm in diam.; hypoprotocetraric or subpsoromic acid 12

12a. Subpsoromic acid ..... ***O. praestans***
12b. Hypoprotocetraric acid ..... ***O.*** aff. ***praestans***

Ocellularia bahiana (Ach.) A. Frisch (FIG. 23A)

Specimens examined. ALAGOAS: Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (closed forest), 50 m, *Cáceres & Lücking 01-0600* (B, F, URM), *01-0525* (URM), *01-0553* (F), *02-0002* (B, F, URM), *M. Cáceres 2005* (F), *02-2006* (F, URM), *s.n.* (B, F). Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (forest along main trail), 50 m, *M. Cáceres A02-400* (F), *A08-063* (B, F, URM).

Ocellularia cavata (Ach.) Müll. Arg. (FIG. 23B)

Specimens examined. PERNAMBUCO: Caruaru, Brejo dos Cavalos, 8° 20' S, 35° 58' W, Brejo de Altitude (high altitude rainforest), 800–900 m, *Cáceres & Lücking 00-0557* (F, URM). Recife, Dois Irmãos, Mata Atlântica (closed forest), *Cáceres & Lücking 99-0503* (F).

Ocellularia crocea (Kremp.) Overeem & D. Overeem

Specimens examined. PERNAMBUCO: Bonito, Parque Municipal de Bonito, 8° 28' S, 35°43' W, Brejo de Altitude (high altitude rainforest), 800 m, *Cáceres & Lücking 00-0320* (B-600124059), *00-0318* (F), *00-0321*(URM), *00-0319* (URM). Igarassu, Refúgio Ecológico Charles Darwin, 7° 50' S, 34° 54' W, Mata Atlântica (closed forest), 20 m, *Cáceres & Lücking 00-0460* (B, F), *00-0461* (B, F).

Ocellularia gracilis Müll. Arg. (FIG. 23C)

Specimens examined. PERNAMBUCO: Caruaru, Brejo dos Cavalos, 8° 20' S, 35° 58' W, Brejo de Altitude (high altitude rainforest), 800–900 m, *Cáceres & Lücking 00-0599f* (B-600124028), *00-0615* (B-600124060, F, URM), *00-0616* (F).

Ocellularia landronii Hale (FIG. 23D)

Specimens examined. ALAGOAS: Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (closed forest), 50 m, *Cáceres & Lücking 01-0105* (B, F, URM).

Ocellularia mauritiana Hale (FIG. 23E)

Specimens examined. PERNAMBUCO: Caruaru, Brejo dos Cavalos, 8° 20' S, 35° 58' W, Brejo de Altitude (high altitude rainforest), 800–900 m, *Cáceres & Lücking 00-0558* (B, F, URM), *00-0556* (F).

Ocellularia papillata (Leight.) Zahlbr. (FIG. 23F)

Specimens examined. ALAGOAS: Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (closed forest), 50 m, *Cáceres & Lücking 01-0581* (B, F). Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (forest along main trail), 50 m, *M. Cáceres A10-094* (F), *A23-198* (F), *A46-42* (F), *A46-425* (F), *A46-425a* (F). RIO GRANDE DO NORTE: Baía Formosa, Reserva Particular do Patrimônio Natural (RPPN) Mata Estrela Senador Antônio Farias, 06° 22' S, 35° 01' W, Mata Atlântica (closed forest), 0 m, *M. Cáceres 01-0171* (F), *01-0177* (URM).

Ocellularia praestans (Müll. Arg.) Hale (FIG. 23G)

Specimen examined. PERNAMBUCO: Cabo de Santo Agostinho, Reserva Ecológica de Gurjaú, 8° 19' S, 35° 04' W, Mata Atlântica (closed forest), 30 m, *Cáceres & Lücking 00-0169* (F, URM).

Ocellularia aff. ***praestans*** (Müll. Arg.) Hale (FIG. 23H)

Notes. This material agrees with *Ocellularia praestans* in all characters except that simultaneous TLC reveals two slightly differentiated spots corresponding to subpsoromic and hypoprotocetraric acid, respectively, suggesting that it deals with a chemically differentiated taxon.

Specimen examined. ALAGOAS: Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (closed forest), 50 m, *M. Cáceres 2063* (F, URM).

Ocellularia subemersa Müll. Arg.

Specimen examined. ALAGOAS: Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (closed forest), 50 m, *Cáceres & Lücking 01-0510* (B, F).

Ocellularia spec. A

Notes. The following three species produce soralia only and on account of their thallus morphology belong in the difficult group of sorediate, frequently sterile species of *Ocellularia* (EMMERER & HAFELLNER 2004). *Ocellularia* spec. A has reddish soralia containing norstictic acid, while *Ocellularia* spec. B has pale yellow and *Ocellularia* spec. C greenish white soralia.

Specimens examined. PERNAMBUCO: Cabo de Santo Agostinho, Reserva Ecológica de Gurjaú, 8° 19' S, 35° 04' W, Mata Atlântica (closed forest), 30 m, *Cáceres & Lücking 00-0189* (F). Igarassu, Refúgio Ecológico Charles Darwin, 7° 50' S, 34° 54' W, Mata Atlântica (closed forest), 20 m, *Cáceres & Lücking 00-0406* (F), *00-0407* (F).

Ocellularia spec. B

Specimens examined. ALAGOAS: Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (forest along main trail), 50 m, *M. Cáceres A13-124* (F), *A19-177* (F), *A46-413* (F). PERNAMBUCO: Bonito, Parque Municipal de Bonito, 8° 28' S, 35°43' W, Brejo de Altitude (high altitude rainforest), 800 m, *Cáceres & Lücking 00-0292* (F), *00-0298* (F).

Ocellularia spec. C

Specimens examined. ALAGOAS: Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (forest along main trail), 50 m, *M. Cáceres A01-004a* (F), *A01-007b* (F), *A01-009* (F), *A09-071* (F), *A09-075* (F), *A09-083* (F), *A18-164* (F).

Ochrolechia A. Massal. (Pertusariaceae)

Notes. Species of *Ochrolechia* are recognized by their comparatively large, seemingly lecanorine but actually zeorine apothecia and rather large ascospores. The genus is not very species rich in tropical regions but a few taxa are abundantly found in more exposed or drier situations.

Ochrolechia africana Vain. (FIG. 24A)

Specimens examined. PERNAMBUCO: Caruaru, Instituto Pernambucano de Pesquisas Agropecuárias (IPA), 8° 17' S, 35° 58' W secondary vegetation (open area in front of main building), 500–600 m, *Cáceres & Lücking 00-0122* (B-600124061, F, URM). SERGIPE: Gararu, 9° 58' S, 37° 54' W, Caatinga (thornbush), 0–100 m, *M. Cáceres 2094* (F, URM).

Opegrapha Ach. (Roccellaceae)

Notes. *Opegrapha* is one of the most abundant genera in tropical lowland rainforest and yet one of the least well-known. Except for extratropical and lichenicolous taxa, the genus is practically unstudied, and the only modern treatment of tropical taxa exists for India (URMILA & MAKHIJA 1987). The only available treatment for the Neotropics is REDINGER (1940), but many of the present specimens do not fit his descriptions exactly. There are also errors in his treatment, since species with exposed disc, such as *O. contracta* (type seen) and *O. quintana*, are described by him as having ascomata with concealed disc. Of the 19 species treated by HARRIS (1995) for subtropical Florida, a treatment very helpful for many tropical groups, eight remained unnamed.

Key to species of *Opegrapha*

1a. Ascospores 1–3-septate 2
1b. Ascospores 5–13-septate 4

2a. Ascospores 15–18 µm long; ascomata robust ..... ***O.*** cf. ***aperiens***
2b. Ascospores 10–12 µm long; ascomata small..... 3

3a. Ascospores thin-walled; thallus verruculose, green ... ***O.*** cf. ***millegrana***
3b. Ascospores thick-walled; thallus smooth, grey ..... ***O. atratula***

4a. Ascospores 5–7-septate, 25–45 µm long..... 5
4b. Ascospores 7–13-septate, 45–65 µm long..... 9

5a. Ascospores 5-septate, 25–30 µm long; thallus white ..... ***O.*** cf. ***arengae***
5b. Ascospores (5–)7-septate, 30–45 µm long; thallus green-brown..... 6

6a. Disc exposed.....***O. quintana***
6b. Disc concealed..... 7

7a. Thallus brown; ascomata irregular, robust ..... ***O.*** aff. ***quintana***
7b. Thallus green; ascomata in stellate clusters, slender 8

8a. Ascospores 30–35 µm long; thallus smooth.....***O.*** aff. ***cylindrica***
8b. Ascospores 35–50 µm long; thallus pustulose ..... ***O. cylindrica***

9a. Thallus pustulose 10
9b. Thallus smooth 11

10a. Disc exposed; ascospores 50–60 μm long; ascomata robust.....
.....***O.*** cf. ***urosperma***
10b. Disc concealed; ascospores 35–50 μm long; ascomata slender
..... ***O. cylindrica***

11a. Disc concealed; ascomata very elongate, sparsely branched .....
..... ***O.*** cf. ***robusta***
11b. Disc exposed; ascomata robust, irregularly branched 12

12a. Thallus grey; ascomata short ..... ***O.*** cf. ***contracta***
12b. Thallus green; ascomata elongate..... ***O.*** aff. ***contracta***

Opegrapha cf. ***aperiens*** Vain.

Specimens examined. ALAGOAS: Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (forest along main trail), 50 m, *M. Cáceres A24-196a* (F), *A24-198* (F), *A40-304a* (F).

Opegrapha cf. ***arengae*** Vain. (FIG. 24B)

Specimens examined. ALAGOAS: Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (forest along main trail), 50 m, *M. Cáceres A15-137* (F), *A44-345* (F), *A44-350* (F). PERNAMBUCO: Igarassu, Refúgio Ecológico Charles Darwin, 7° 50' S, 34° 54' W, Mata Atlântica (closed forest), 20 m, *Cáceres & Lücking 00-0500* (F). Recife, Dois Irmãos, Mata Atlântica (closed forest), *Cáceres & Lücking 99-0500* (B, F, URM).

Opegrapha atratula Müll. Arg. (FIG. 24C)

Specimens examined. ALAGOAS: Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (forest along main trail), 50 m, *M. Cáceres A25-216* (F). PERNAMBUCO: Caruaru, Brejo dos Cavalos, 8° 20' S, 35° 58' W, Brejo de Altitude (high altitude rainforest), 800–900 m, *Cáceres & Lücking 00-0552* (F, URM).

Opegrapha cf. ***contracta*** Vain.

Specimen examined. PERNAMBUCO: Cabo de Santo Agostinho, Reserva Ecológica de Gurjaú, 8° 19' S, 35° 04' W, Mata Atlântica (closed forest), 30 m, *Cáceres & Lücking 00-0197* (B, F, URM).

Opegrapha aff. ***contracta*** Vain. (FIG. 24D)

Notes. The abundant material is characterized by rather large, robust, sessile ascomata with exposed disc and large (45–65 × 5–7 μm), 7–13-septate ascospores. It agrees with the preceeding taxon except for the more elongate ascomata and green instead of grey thallus.

Specimens examined. ALAGOAS: Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (closed forest), 50 m, *Cáceres & Lücking 01-0067* (F), *01-0114* (F), *01-0123* (F), *01-0524* (F), *M. Cáceres s.n.* (F, URM), *s.n.* (B, F, URM), *Cáceres & Lücking 01-0029* (URM), *01-0040* (URM), *01-0042* (B). Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (forest along main trail), 50 m, *M. Cáceres A01-013* (F), *A09-075a* (F), *A09-086* (F), *A09-087* (F), *A09-091* (F), *A10-098d* (F), *A12-114b* (F), *A16-143* (F), *A18-170* (F), *A23-196* (F), *A24-196* (F), *A24-204* (F), *A25-211* (F), *A25-212* (F), *A25-213b* (F), *A25-217a* (F), *A25-218* (F), *A26-222* (F), *A26-225* (F), *A26-226* (F), *A30-245* (F), *A33-253* (F), *A37-284* (F), *A37-285d* (F), *A41-323* (F), *A46-412* (F), *A46-413a* (F), *A46-416a* (F), *A46-417b* (F), *A46-425* (F), *A46-425b* (F), *A47-449* (F). PERNAMBUCO: Cabo de Santo Agostinho, Reserva Ecológica de Gurjaú, 8° 19' S, 35° 04' W, Mata Atlântica (closed forest), 30 m, *Cáceres & Lücking 00-0155* (B, F), *00-0154* (URM). Caruaru, Brejo dos Cavalos, 8° 20' S, 35° 58' W, Brejo de Altitude (high altitude rainforest), 800–900 m, *Cáceres & Lücking 00-0560* (F, URM), *s.n.* (URM). Igarassu, Refúgio Ecológico Charles Darwin, 7° 50' S, 34° 54' W, Mata Atlântica (closed forest), 20 m, *Cáceres & Lücking 00-0509* (F). RIO GRANDE DO NORTE: Baía Formosa, Reserva Particular do Patrimônio Natural (RPPN) Mata Estrela Senador Antônio Farias, 06° 22' S, 35° 01' W, Mata Atlântica (closed forest), 0 m, *M. Cáceres 01-0169* (F). SERGIPE: Santa Luzia, Private property, 11° 19' S, 37° 27' W, Mata Atlântica (closed forest), *Cáceres & Lücking 00-0830* (F), *00-0870* (B, F, URM).

Opegrapha cylindrica Raddi

Specimens examined. PERNAMBUCO: Igarassu, Refúgio Ecológico Charles Darwin, 7° 50' S, 34° 54' W, Mata Atlântica (closed forest), 20 m, *Cáceres & Lücking 00-0510* (F) , *00-0512* (B), *00-0513* (F), *00-0514* (F), *00-0515* (B, F, URM), *00-0516* (B, F, URM). SERGIPE: Santa Luzia, Private property, 11° 19' S, 37° 27' W, Mata Atlântica (closed forest), *Cáceres & Lücking s.n.* (F).

Opegrapha aff. ***cylindrica*** Raddi

Notes. This material is very similar to the preceeding taxon but has distinctly smaller ascospores with less septa.

Specimen examined. PERNAMBUCO: Igarassu, Refúgio Ecológico Charles Darwin, 7° 50' S, 34° 54' W, Mata Atlântica (closed forest), 20 m, *Cáceres & Lücking 00-0506* (F).

Opegrapha cf. ***millegrana*** Redinger (FIG. 24E)

Notes. This material is characterized by its distinctly verruculose thallus and short ascomata with often slightly exposed disc. Based on the description, *Opegrapha millegrana* comes close, by authentic material has not been checked.

Specimen examined. PERNAMBUCO: Igarassu, Refúgio Ecológico Charles Darwin, 7° 50' S, 34° 54' W, Mata Atlântica (closed forest), 20 m, *Cáceres & Lücking 00-0507* (B, F).

Opegrapha quintana Redinger (FIG. 24F)

Specimen examined. SERGIPE: Areia Branca, Reserva Ecológica Serra de Itabaiana, 10° 45' S, 37° 20' W, Mata Atlântica (closed forest), 500 m, *Cáceres & Lücking 2210* (F).

Opegrapha aff. ***quintana*** Vain.

Notes. No name was found for this taxon which resembles *Opegrapha quintana* in ascospore type but has ascomata with concealed discs and a brown thallus. A similarly colored thallus was described for *O. fuscula* Redinger and *O. obscurata* Redinger, but those species have much smaller ascospores.

Specimens examined. PERNAMBUCO: Bonito, Parque Municipal de Bonito, 8° 28' S, 35°43' W, Brejo de Altitude (high altitude rainforest), 800 m, *Cáceres & Lücking 00-0364* (B, F), *00-0365* (F). Cabo de Santo Agostinho, Reserva Ecológica de Gurjaú, 8° 19' S, 35° 04' W, Mata Atlântica (closed forest), 30 m, *Cáceres & Lücking 00-0153* (F).

Opegrapha cf. ***robusta*** Vain. (FIG. 24G)

Specimens examined. SERGIPE: Santa Luzia, Private property, 11° 19' S, 37° 27' W, Mata Atlântica (closed forest), *Cáceres & Lücking 00-0827* (B, F, URM), *00-0843* (B, F, URM), *00-0845* (F).

Opegrapha cf. ***urosperma*** Fée (FIG. 24H)

Notes. The specimens are similar to *Opegrapha* aff. *contracta* in ascomata and ascospore type but differ in their verruculose-pustulose thallus, which is typical of *O. urosperma*. However, the ascospores of the latter are usually slightly larger.

Specimens examined. ALAGOAS: Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (forest along main trail), 50 m, *M. Cáceres A19-174* (F). PERNAMBUCO: Igarassu, Refúgio Ecológico Charles Darwin, 7° 50' S, 34° 54' W, Mata Atlântica (closed forest), 20 m, *Cáceres & Lücking 00-0511* (B, F, URM).

Pertusaria DC. (Pertusariaceae)

Notes. Pertusaria is one of the most speciose lichen genera, usually recognized by its apothecia aggregate in thalline warts and with rather narrow openings, often resembling perithecia, in combination with large, thick-walled, non-septate ascospores. The genus is well-known in extratropical areas and in Australia (ARCHER 1993, 1997, 2004; LUMBSCH & NASH 1999). Secondary chemistry is quite rich and variable (DIBBEN 1980) and could be shown to correlate with the phylogeny of the genus sensu lato, which is now

split into three genera (ARCHER 1997; LUMBSCH & SCHMITT 2001; SCHMITT *et al.* 2003; SCHMITT & LUMBSCH 2004).

Key to species of *Pertusaria*

1a. Soralia present 2
1b. Soralia absent..... 3

2a. Thallus UV+ yellow; asci 1-spored.....***P. ventosa***
2b. Thallus UV–; apothecia absent.....***P.*** spec.

3a. Asci 8-spored..... 4
3b. Asci 2–4-spored..... 5

4a. Thallus grey, UV+ yellow (lichexanthone), K+ yellow (stictic acid); apothecial warts white-grey, with immersed, darker ostiolar area..... .....***P. dehiscens***
4b. Thallus yellow-green, UV+ orange (thiophaninic acid), K–; apothecial warts yellow-green, with prominent, yellow-orange ostiolar area..... .....***P. flavens***

5a. Thallus yellow-green (thiophaninic acid), K+ yellow then red (norstictic acid) .....***P. wulfenioides***
5b. Thallus grey, K+ yellow or K–..... 6

6a. Thallus UV–, K–; asci 2-spored .....***P. carneola***
6b. Thallus UV+ orange (4,5-dichlorolichexanthone), K+ yellow (stictic acid); asci 4-spored..... 7

7a. Thallus smooth; apothecial warts prominent, smooth..***P. tetrathalamia***
7b. Thallus verrucose; apothecial warts sessile, irregular .....***P. quassiae***

Pertusaria carneola (Eschw.) Müll. Arg. (FIG. 25A)

Specimen examined. PERNAMBUCO: Caruaru, Instituto Pernambucano de Pesquisas Agropecuárias (IPA), 8° 17' S, 35° 58' W, Caatinga (open thornbush), 500–600 m, *Cáceres & Lücking 00-0065* (F).

Pertusaria dehiscens Müll. Arg. (FIG. 25B)

Specimen examined. PERNAMBUCO: Caruaru, Instituto Pernambucano de Pesquisas Agropecuárias (IPA), 8° 17' S, 35° 58' W, Caatinga (open thornbush), 500–600 m, *Cáceres & Lücking 00-0028* (F).

Pertusaria flavens Nyl. (FIG. 25C)

Specimens examined. PERNAMBUCO: Caruaru, Brejo dos Cavalos, 8° 20' S, 35° 58' W, secondary vegetation (fence posts), 800–900 m, *Cáceres & Lücking 00-0807b* (B-600124157), *00-0803d* (F), *00-0808b* (F). Caruaru, Instituto Pernambucano de Pesquisas Agropecuárias (IPA), 8° 17' S, 35° 58' W, Caatinga (open thornbush), 500–600 m, *Cáceres & Lücking 00-0056* (B-600124064), *00-0030* (F). SERGIPE: Gararu, 9° 58' S, 37° 54' W, Caatinga (thornbush), 0–100 m, *M. Cáceres 2116* (B), *2093a* (F), *2105* (F, URM), *2117* (F, URM), *2125c* (F), *2154* (F).

Pertusaria quassiae (Fée) Nyl. (FIG. 25D)

Specimens examined. PERNAMBUCO: Caruaru, Brejo dos Cavalos, 8° 20' S, 35° 58' W, secondary vegetation (fence posts), 800–900 m, *Cáceres & Lücking 00-0803c* (F). Caruaru, Instituto Pernambucano de Pesquisas Agropecuárias (IPA), 8° 17' S, 35° 58' W, Caatinga (open thornbush), 500–600 m, *Cáceres & Lücking 00-0027* (B-600124065, F). SERGIPE: Itabi, Private property, 10° 06' S, 37° 54' W, Caatinga (thornbush), 100 m, *M. Cáceres 2196* (B). Ribeira, Mata Atlântica, *M. Cáceres 2065* (F, URM).

Pertusaria tetrathalamia (Fée) Nyl. (FIG. 25E)

Specimens examined. PERNAMBUCO: Caruaru, Brejo dos Cavalos, 8° 20' S, 35° 58' W, Brejo de Altitude (high altitude rainforest), 800–900 m, *Cáceres & Lücking 00-0553* (B-600124066, F, URM). SERGIPE: Gararu, 9° 58' S, 37° 54' W, Caatinga (thornbush), 0–100 m, *Cáceres 2111a* (F).

Pertusaria ventosa Malme (FIG. 25F)

Specimens examined. PERNAMBUCO: Caruaru, Instituto Pernambucano de Pesquisas Agropecuárias (IPA), 8° 17' S, 35° 58' W, Caatinga (open thornbush), 500–600 m, *Cáceres & Lücking 00-0022* (F, URM), *00-0093a* (F).

Pertusaria wulfenioides De Lesd. (FIG. 25G)

Specimen examined. SERGIPE: Gararu, 9° 58' S, 37° 54' W, Caatinga (thornbush), 0–100 m, *M. Cáceres 2111b* (F).

Pertusaria spec. (FIG. 25H)

Specimens examined. PERNAMBUCO: Caruaru, Brejo dos Cavalos, 8° 20' S, 35° 58' W, Brejo de Altitude (high altitude rainforest), 800–900 m, *Cáceres & Lücking 00-0546* (B, URM), *00-0544* (F), *00-0638* (F).

Phaeographis Müll. Arg. (Graphidaceae)

Notes. This genus traditionally included species with transversely septate, brown ascospores, but in its modern sense is restricted to taxa with exposed disc and thin labia lacking or with little carbonization, usually inspersed

hymenium, and brown, I+ vine-red, transversely septate to muriform ascospores (STAIGER 2002).

Key to species of *Phaeographis*

1a. Ascospores transversely septate 2
1b. Ascospores muriform 12

2a. Hymenium clear 3
2b. Hymenium inspersed 7

3a. Norstictic acid (thallus in sections K+ yellow then red, forming needle-shaped crystals) 4
3b. Neotricone or no substances, thallus in sections K– 6

4a. Lirellae aggregate in pseudostromata with orange-red, K+ purple pigment when sectioned ..... ***P. rubrostroma***
4b. Lirellae solitary or in pseudostromata but lacking red pigment 5

5a. Lirellae aggregate in pseudostromata; ascospores 3-septate, 14–20 µm long ..... ***P. brasiliensis***
5b. Lirellae solitary to aggregate but not forming pseudostromata; ascospores 5-septate, 20–26 µm long ..... ***P. crispata***

6a. Lirellae prominent (resembling *Platythecium*); ascospores 3-septate, 15–20 µm long ..... ***P.*** aff. ***neotricosa***
6b. Lirellae immersed-erumpent; ascospores 3–5-septate, 17–25 µm long ..... ***P. neotricosa***

7a. Thallus UV+ yellow (lichexanthone); apothecia almost rounded, very small, with thin, non-prominent thalline margin ..... ***P. punctiformis***
7b. Thallus UV–; apothecia lirellate, if round then large and with prominent, lobulate thalline margin 8

8a. Apothecia round, with prominent, lobulate thalline margin ..... ***P. lobata***
8b. Apothecia lirellate, with thin thalline margin 9

9a. Lirellae with disc red, K+ purple (isohypocrellin) ..... ***P. haematites***
9b. Lirellae with disc grey-brown to black, K– 10

10a. Norstictic acid (thallus in sections K+ yellow then red, forming needle-shaped crystals); ascospores 7–11-septate, 25–45 µm long ..... ***P. dendritica***

10b. No substances (thallus in sections K–); ascospores 5-septate, 15–25 µm long..... 11

11a. Lirellae immersed, small, sparsely branched, with rounded ends..... ..... ***P.*** aff. ***punctiformis***
11b. Lirellae erumpent, conspicuous, branched, with acute ends P. nylanderi

12a. Ascospores 4–8 per ascus, 25–50 × 8–15 µm 13
12b. Ascospores 1–4 per ascus, 85–150 × 20–40 µm 14

13a. Lirellae short, with brown disc; ascospores 40–50 × 13–15 µm..... .....***P.*** aff. ***fusca***
13b. Lirellae elongate, with grey pruinose disc; ascospores 25–40 × 8–14 µm..... ***P. tortuosa***

14a. Lirellae short, with prominent, lobulate thalline margin; norstictic acid .....***P. kalbii***
14b. Lirellae elongate, with thin, entire margin; no substances ....***P. scalpturata***

Phaeographis brasiliensis (A. Massal.) Kalb & Mathes-Leicht (FIG. 26A)

Specimens examined. ALAGOAS: Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (closed forest), 50 m, *Cáceres & Lücking 01-0520c* (F). Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (forest along main trail), 50 m, *M. Cáceres A16-145* (URM). PERNAMBUCO: Caruaru, Brejo dos Cavalos, 8° 20' S, 35° 58' W, Brejo de Altitude (high altitude rainforest), 800–900 m, *Cáceres & Lücking 00-0634* (B-600124068, F). Igarassu, Refúgio Ecológico Charles Darwin, 7° 50' S, 34° 54' W, Mata Atlântica (closed forest), 20 m, *Cáceres & Lücking 00-0522* (B-600124074, F), *00-0528* (F). Recife, Universidade Federal de Pernambuco (UFPE), secondary vegetation on campus, *Cáceres & Lücking 98-s.n.* (F). São Lourenço da Mata, Estação Ecológica de Tapacurá, 8° 02' S, 35° 09' W, Agreste (open dry forest), 100 m, *Cáceres & Lücking 98-0516* (F). SERGIPE: Itabi, Private property, 10° 06' S, 37° 54' W, Caatinga (thornbush), 100 m, *M. Cáceres 2179* (F), *2171* (URM). Santa Luzia, Private property, 11° 19' S, 37° 27' W, Mata Atlântica (closed forest), *Cáceres & Lücking 00-0873* (F), *00-0874* (F), *00-0871* (URM).

Phaeographis crispata Kalb & Mathes-Leicht (FIG. 26B)

Specimens examined. ALAGOAS: Barra de São Miguel, Reserva Particular do Patrimônio Natural (RPPN) Rosa do Sol, 09° 51' S, 35° 53' W, Mata Atlântica (closed forest), 50 m, *M. Cáceres 01-0130* (B), *01-0126* (F), *01-0136* (B). PERNAMBUCO: Cabo de Santo Agostinho, Reserva Ecológica de Gurjaú, 8° 19' S, 35° 04' W, Mata Atlântica (closed forest), 30 m, *Cáceres & Lücking 00-0246* (B, F). RIO GRANDE DO NORTE: Baía Formosa, Reserva Particular do Patrimônio Natural (RPPN) Mata Estrela Senador Antônio Farias, 06° 22' S, 35° 01' W, Mata Atlântica (closed forest), 0 m, *M. Cáceres 01-0192* (URM). SERGIPE:

Santa Luzia, Private property, 11° 19' S, 37° 27' W, Mata Atlântica (closed forest), *Cáceres & Lücking 00-0865* (B, F), *00-0895b* (F), *00-0881* (URM).

Phaeographis dendritica (Ach.) Müll. Arg.

Specimens examined. PERNAMBUCO: Cabo de Santo Agostinho, Reserva Ecológica de Gurjaú, 8° 19' S, 35° 04' W, Mata Atlântica (closed forest), 30 m, *Cáceres & Lücking 00-0150* (B-600124075). Igarassu, Refúgio Ecológico Charles Darwin, 7° 50' S, 34° 54' W, Mata Atlântica (closed forest), 20 m, *Cáceres & Lücking 00-0493* (F).

Phaeographis aff. ***fusca*** Staiger (FIG. 26C)

Specimens examined. ALAGOAS: Barra de São Miguel, Reserva Particular do Patrimônio Natural (RPPN) Rosa do Sol, 09° 51' S, 35° 53' W, Mata Atlântica (closed forest), 50 m, *M. Cáceres 01-0140* (F). PERNAMBUCO: Caruaru, Brejo dos Cavalos, 8° 20' S, 35° 58' W, Brejo de Altitude (high altitude rainforest), 800–900 m, *Cáceres & Lücking 00-0611* (B), *00-0607* (B, F), *00-0612* (F), *00-0644* (F), *00-0610* (URM).

Phaeographis haematites (Fée) Müll. Arg.

Specimens examined. ALAGOAS: Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (closed forest), 50 m, *Cáceres & Lücking 01-0001* (B, F, URM), *01-0531* (F, URM, hb. Kalb). Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (forest along main trail), 50 m, *M. Cáceres A29-241* (B, F, URM), *A40-308* (B, F), *A40-309* (URM). PERNAMBUCO: Bonito, Parque Municipal de Bonito, 8° 28' S, 35°43' W, Brejo de Altitude (high altitude rainforest), 800 m, *Cáceres & Lücking 00-0369* (B-600124073), *00-0368* (F). Cabo de Santo Agostinho, Reserva Ecológica de Gurjaú, 8° 19' S, 35° 04' W, Mata Atlântica (closed forest), 30 m, *Cáceres & Lücking 00-0160* (B-600124072, F, URM), *00-0159* (F, URM). Caruaru, Brejo dos Cavalos, 8° 20' S, 35° 58' W, Brejo de Altitude (high altitude rainforest), 800–900 m, *Cáceres & Lücking 00-0642* (B-600124099). Igarassu, Refúgio Ecológico Charles Darwin, 7° 50' S, 34° 54' W, Mata Atlântica (closed forest), 20 m, *Cáceres & Lücking 00-0494* (URM). Recife, Dois Irmãos, Mata Atlântica (closed forest), *Cáceres & Lücking 98-0502* (B, F, URM).

Phaeographis kalbii Staiger (FIG. 26D)

Specimens examined. PERNAMBUCO: Bonito, Parque Municipal de Bonito, 8° 28' S, 35°43' W, Brejo de Altitude (high altitude rainforest), 800 m, *Cáceres & Lücking 00-0301* (F). Caruaru, Brejo dos Cavalos, 8° 20' S, 35° 58' W, Brejo de Altitude (high altitude rainforest), 800–900 m, *Cáceres & Lücking 00-0639* (B, F, URM).

Phaeographis lobata (Eschw.) Müll. Arg. (FIG. 26E)

Specimens examined. PERNAMBUCO: Caruaru, Brejo dos Cavalos, 8° 20' S, 35° 58' W, Brejo de Altitude (high altitude rainforest), 800–900 m, *Cáceres & Lücking 00-0618* (B, F, URM).

Phaeographis neotricosa Redinger

Specimens examined. PERNAMBUCO: Bonito, Parque Municipal de Bonito, 8° 28' S, 35°43' W, Brejo de Altitude (high altitude rainforest), 800 m, *Cáceres & Lücking 00-0378* (B-600124098), *00-0381* (B-600124101), *00-0379* (URM). Igarassu, Refúgio Ecológico Charles Darwin, 7° 50' S, 34° 54' W, Mata Atlântica (closed forest), 20 m, *Cáceres & Lücking 00-0525* (F), *00-0526* (F), *00-0524* (URM).

Phaeographis aff. ***neotricosa*** Redinger

Notes. This material keyes out close to *Phaeographis neotricosa* but differs clearly in its prominent lirellae resembling those of *Hemithecium* and certain *Platythecium* species.

Specimen examined. PERNAMBUCO: Bonito, Parque Municipal de Bonito, 8° 28' S, 35°43' W, Brejo de Altitude (high altitude rainforest), 800 m, *Cáceres & Lücking 00-0370* (F).

Phaeographis nylanderi (Vain.) Zahlbr.

Specimens examined. PERNAMBUCO: Bonito, Parque Municipal de Bonito, 8° 28' S, 35°43' W, Brejo de Altitude (high altitude rainforest), 800 m, *Cáceres & Lücking 00-0363* (B-600124077, F).

Phaeographis punctiformis (Eschw.) Müll. Arg. (FIG. 26F)

Specimens examined. PERNAMBUCO: Caruaru, Instituto Pernambucano de Pesquisas Agropecuárias (IPA), 8° 17' S, 35° 58' W, Caatinga (open thornbush), 500–600 m, *Cáceres & Lücking 00-0024a* (F). Garanhuns, secondary Caatinga vegetation, *Cáceres & Lücking 98-0501* (B, F).

Phaeographis aff. ***punctiformis*** (Eschw.) Müll. Arg.

Notes. This species closely resembles *Phaeographis punctiformis* but differs by its UV– thallus.

Specimens examined. PERNAMBUCO: Recife, Universidade Federal de Pernambuco (UFPE), secondary vegetation on campus, *Cáceres & Lücking 98-s.n.* (F). SERGIPE: Santa Luzia, Private property, 11° 19' S, 37° 27' W, Mata Atlântica (closed forest), *Cáceres & Lücking 00-0879* (F).

Phaeographis rubrostroma Cáceres & Lücking **spec. nova** (FIG. 26G)

Phaeographis intricante pseudotromata in parte basali aurantiaco-rubra differt. — **Typus.** PERNAMBUCO: Caruaru, Brejo dos Cavalos, 8° 20' S, 35° 58' W, Brejo de Altitude (high altitude rainforest), 800–900 m, *Cáceres & Lücking 00-0634* (B, holotypus; F, isotypus).

Description. Thallus crustose, corticolous, 30–70 mm across and 30–50 µm thick, continuous, smooth, with cartilaginous cortex, olive green. Photobiont

Trentepohlia; cells angular-rounded, 7–12 µm diam. Lirellae in pseudostromata, flexuose, stellately branched and completely confluent, immersed but flush with margin of pseudostromata, the latter 1–5 mm across, with irregular outline, the lirellae 1–5 mm long and 0.15–0.25 mm wide, 0.1–0.13 mm high; pseudostromata in section with triangular pockets of orange-red, K+ bright red crystals between individual lirellae and the same crystals also at their base; margin of pseudostromata white, disc of lirellae brown-black but with a thin white pruina, the orange-red color of the crystals visible in the splits between the lirellae. Excipulum indictinct, 5–10 µm wide, light brown; hypothecium prosoplectenchymatous, 20–30 µm high, colorless to pale yellow; hymenium 80–100 µm high, colorless, clear. Epithecium indistinct. Paraphyses unbranched. Asci clavate, 80–90 × 12–16 µm. Ascospores 8 per ascus, oblong, (3–)5-septate, 15–22 × 5–7 µm, 3–4 times as long as wide, grey-brown, I+ vine-red. Secondary chemistry: norstictic acid, connorstictic acid, unknown orange-red anthraquinone.

Notes. Phaeographis rubrostroma is a typical member of the *P. intricans* group (STAIGER 2002) and closely related to *P. intricans* itself. The latter has the same lirellae morphology, with distinct pseudostroma formation, and the same type of ascospores, but lacks the conspicuous orange-red pigment. To our knowledge, the occurrence of such a pigment is so far unknown in the *P. intricans* group.

Phaeographis scalpturata (Ach.) Staiger

Specimens examined. ALAGOAS: Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (closed forest), 50 m, *Cáceres & Lücking 01-0520b* (F), *01-0523* (B, F). Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (forest along main trail), 50 m, *M. Cáceres A32-247* (B, URM).

Phaeographis tortuosa (Ach.) Müll. Arg. (FIG. 26H)

Specimens examined. ALAGOAS: Barra de São Miguel, Reserva Particular do Patrimônio Natural (RPPN) Rosa do Sol, 09° 51' S, 35° 53' W, Mata Atlântica (closed forest), 50 m, *M. Cáceres 01-0148* (F). Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (closed forest), 50 m, *Cáceres & Lücking 01-0007* (F, URM), *01-0529c* (F). PERNAMBUCO: Igarassu, Refúgio Ecológico Charles Darwin, 7° 50' S, 34° 54' W, Mata Atlântica (closed forest), 20 m, *Cáceres & Lücking 00-0518* (B, F). Recife, Universidade Federal de Pernambuco (UFPE), secondary vegetation on campus, *Cáceres & Lücking 98-s.n.* (URM). SERGIPE: Itabi, Private property, 10° 06' S, 37° 54' W, Caatinga (thornbush), 100 m, *M. Cáceres 2172* (B), *2156* (B, F, URM).

Phlyctella Kremp. (Phlyctidaceae)

Notes. The Phlyctidaceae were until recently considered to be part of the Lecanorales, but molecular phylogenetic analysis indicates that they belong in Ostropales s.lat. (MIADLIKOWSKA et al. 2006). This is in line with their general morphology, since the species closely resemble *Chroodiscus* and similar genera in the Thelotremataceae. The main difference is the amyloid hymenium and chlorococcoid photobiont.

Phlyctella brasiliensis (Nyl.) Nyl. (FIG. 27A)

Specimen examined. PERNAMBUCO: Bonito, Parque Municipal de Bonito, 8° 28' S, 35°43' W, Brejo de Altitude (high altitude rainforest), 800 m, *Cáceres & Lücking 00-0294* (B-600124078, F).

Phyllopsora Müll. Arg. (Ramalinaceae)

Notes. The genus *Phyllopsora* is a characteristic element of tropical rainforest lichen communities, easily recognized at genus level by its squamulose thallus resting on a byssoid prothallus and mostly orange-brown, emarginate apothecia producing small, non-septate ascospores (BRAKO 1989; SWINSCOW & KROG 1981). The genus was monographed for the Neotropics by BRAKO (1991), but their species concept using abundant infraspecific entities for chemical and morphological variation is not tenable, and the more natural approach of TIMDAL & KROG (2001) is followed here.

Key to species of *Phyllopsora*

1a. Thallus microfoliose; squamules 0.5–1.0 mm in diam; flattened lobules abundant ..... ***P. parvifolia***
1b. Thallus squamulose; squamules 0.1–0.5 mm in diam.; flattened lobules absent 2

2a. Squamules 0.1 mm in diam.; thallus almost crustose, resembling *Malcolmiella*; apothecia with orange pigment internally; furfuracein .... ***P. furfuracea***
2b. Squamules 0.1–0.5 mm in diam.; thallus distinctly squamulose; apothecia lacking orange pigment; secondary chemistry different 3

3a. Isidia flattened; ascospores 12–19 × 3–4 µm ..... ***P. longiuscula***
3b. Isidia not flattened; ascospores 6–12 × 2.5–3.5 µm 4

4a. Squamules 0.2–0.5 mm in diam.; isidia cylindrical, short .. ***P. corallina***
4b. Squamules 0.1–0.3 mm in diam.; isidia globose or inflated 5

5a. Isidia globose, proliferating ..... ***P. kalbii***

5b. Isidia elongate..... ***P. intermediella***

Phyllopsora corallina (Eschw.) Müll. Arg. (FIG. 27B)

Specimens examined. SERGIPE: Itabaiana, Fazenda São Jose, 10° 45' S, 37° 20' W, Mata Atlântica (closed forest), 500 m, *Cáceres 2062* (F, URM). SERGIPE: Ribeira, Mata Atlântica, *Cáceres 2037* (F).

Phyllopsora furfuracea (Pers.) Zahlbr. (FIG. 27C)

Specimens examined. ALAGOAS: Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (closed forest), 50 m, *Cáceres & Lücking 01-0052* (B, F), *01-0044* (F, URM), *01-0066* (F), *01-0101* (F, URM), *01-0538* (F), *01-0580* (F), *01-0097* (URM). Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (forest along main trail), 50 m, *M. Cáceres A13-129* (B, URM), *A21-192* (B, F). PERNAMBUCO: Bonito, Parque Municipal de Bonito, 8° 28' S, 35°43' W, Brejo de Altitude (high altitude rainforest), 800 m, *Cáceres & Lücking 00-0341* (B-600124278).

Phyllopsora intermediella (Nyl.) Zahlbr. (FIG. 27D)

Specimens examined. PERNAMBUCO: Bonito, Parque Municipal de Bonito, 8° 28' S, 35°43' W, Brejo de Altitude (high altitude rainforest), 800 m, *Cáceres & Lücking 00-0335* (B-600124097, F), *00-0281* (F, URM).

Phyllopsora kalbii Brako (FIG. 27E)

Specimen examined. SERGIPE: Itabi, Private property, 10° 06' S, 37° 54' W, Caatinga (thornbush), 100 m, *M. Cáceres 2169* (B, F, URM).

Phyllopsora longiuscula (Nyl.) Zahlbr.

Specimen examined. ALAGOAS: Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (forest along main trail), 50 m, *M. Cáceres A13-127* (F).

Phyllopsora parvifolia (Pers.) Müll. Arg.

Specimens examined. ALAGOAS: Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (forest along main trail), 50 m, *M. Cáceres A35-274c* (F), *A36-277b* (F), *A36-280e* (URM), *A37-287d* (F).

Physcia (Schreb.) Michx. (Physciaceae)

Notes. Physcia forms the natural center of the foliose Physciaceae, but in the tropics is usually more speciose and abundant at mid elevations in humid climates (MOBERG 1990). Only two species were found in the present mate-

rial. A further species, *P. atrostriata* Moberg, was reported by Moberg (1990) from Pernambuco.

Key to species of *Physcia*

1a. Soralia elongate, marginal; undersite pale with dark striae and long rhizines (*Peltigera*-like).....***P. atrostriata***
1b. Soralia maculate, marginal to laminal; undersite pale or dark but lacking striae and with short rhizines 2

2a. Underside white to grey.....***P. rolfii***
2b. Underside black ..... ***P. sorediosa***

Physcia rolfii Moberg

Specimen examined. SERGIPE: Itabi, Private property, 10° 06' S, 37° 54' W, Caatinga (thornbush), 100 m, *M. Cáceres 2174* (F, URM).

Physcia sorediosa (Vain.) Lynge

Specimens examined. SERGIPE: Itabi, Private property, 10° 06' S, 37° 54' W, Caatinga (thornbush), 100 m, *M. Cáceres 2159* (F, URM), *2167* (F), *2182* (F), *2183* (F), *2158* (URM).

Platygramme Fée (Graphidaceae)

Notes. Platygramme was reinstated by STAIGER (2002) as a segregate of *Phaeographis* and *Phaeographina*, respectively, to accommodate species with *Phaeographis*-type hymenium and ascospores, but strongly prominent lirellae with well-developed, carbonized labia. The most commonly collected species is *P. caesiopruinosa*, characterized by its bluish pruinose discs. Two further species, *P. reticulata* (Fée) Fée and *P. norstictica* ined. are known from Bahia but not from the five states studied here (STAIGER 2002).

Platygramme caesiopruinosa (Fée) Fée (FIG. 27F)

Specimens examined. PERNAMBUCO: Caruaru, Brejo dos Cavalos, 8° 20' S, 35° 58' W, Brejo de Altitude (high altitude rainforest), 800–900 m, *Cáceres & Lücking 00-0656* (B-600124069).

Platythecium Staiger (Graphidaceae)

Notes. Platythecium is a new genus introduced by STAIGER (2002) for species with exposed disc but well-developed labia lacking carbonization, in combination with colorless, comparatively small ascospores. Staiger (2002)

reported three species from Bahia, *P. allosporellum* (Nyl.) Staiger, *P. colliculosum* (Mont.) Staiger, and *P. grammitis* (Fée) Staiger, but this is the first report of the genus for the five northeastern coastal states studied here and apparently the first record of *P. dimorphodes* for the Neotropics.

Platythecium dimorphodes (Nyl.) Staiger (FIG. 27G)

Specimen examined. PERNAMBUCO: Igarassu, Refúgio Ecológico Charles Darwin, 7° 50' S, 34° 54' W, Mata Atlântica (closed forest), 20 m, *Cáceres & Lücking 00-0398* (F).

Plectocarpon Fée (Roccellaceae)

Notes. The genus *Plectocarpon*, recently monographed by ERTZ *et al.* (2005), thus far contained only lichenicolous species (GRUBE 1998). The new species described below is the first lichenized member of the genus. The generic identify of the new species was confirmed by D. Ertz and P. Diederich (pres. comm. 2006).

Plectocarpon syncesioides Cáceres & Lücking **spec. nova** (FIG. 27H)

Lichenisatus, thallo acidum norsticticum continente. Ascosporae 5-septatae. — Typus. ALAGOAS: Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (forest along main trail), 50 m, *M. Cáceres A15-133* (URM, holotypus; B, F, isotypi).

Description. Thallus crustose, corticolous, covering large areas of the substrate, 30–50 µm thick, continuous, farinose, ecorticate, pale yellow (K+ yellow then red), in section composed of irregular to anticlinal, free hyphae; thin black prothallus usually present. Photobiont *Trentepohlia*; cells angular-rounded, 5–10 µm diam. Lirellae in stromata, flexuose, stellately branched and completely confluent, immersed, stromata 0.5–2 mm across and 150–200 µm high, rounded to irregular, lirellae 0.3–1.5 mm long and 0.05–0.15 mm wide; stromata in section completely carbonized or rarely with paler areas between individual lirellae, in thin sections and above hymenium revealing a tissue of loosely woven, olive-brown hyphae; surface of stromata pale grey-brown pruinose, disc of lirellae brown-black, non-pruinose. Loculi 50–150 µm wide and 80–100 µm high; hymenium 70–80 µm high, colorless to pale yellow, I+ orange-yellow, KI+ pale blue. Paraphyses branched and anastomosing. Asci clavate, 60–70 × 9–12 µm. Ascospores 8 per ascus, fusiform with slightly tapering proximal end, 5-septate, 20–28 × 4–5.5 µm, 4.5–5.5 times as long as wide, colorless. Pycnidia abundant, concentrated within a thin marginal zone of the thallus, sessile, subglobose to egg-shaped, 0.1 mm diam., dark grey. Conidia ellipsoid to bacillar, non-septate, 3–4 × 1.5–2 µm, colorless. Secondary chemistry: norstictic acid.

Notes. This enigmatic taxon has puzzled us for quite some time regarding its generic placement. The overall thallus morphology and anatomy and the ecology give the impression of a species of *Syncesia*, but that genus has only partially carbonized, rounded ascomata grouped in pseudostromata, the ascospores are always 3-septate, and norstictic acid is unknown in that genus. Several other lichenized, stromatic genera within Roccellaceae come to mind, such as *Chiodecton* and its allies (THOR 1990), but all differ in important anatomical and/or morphological details. The only genus with the same type of stromatic ascomata is *Plectocarpon*, but thus far, only lichenicolous taxa have been accepted in that genus (ERTZ *et al.* 2005). Yet, the present material fits *Plectocarpon* in all aspects of the ascomata, including completely carbonized stromata, lirellate ascomata, and *Opegrapha* type hymenium and ascospores. We therefore see no other alternative than placing this taxon in *Plectocarpon* for the time being, even if it represents the first genuinely lichenized species included in this genus.

Polymeridium (Müll. Arg.) R.C. Harris (Trypetheliaceae)

Notes. Polymeridium is a rather inconspicuous though widespread and speciose genus of the Trypetheliaceae, characterized by solitary, black perithecia and ascospores with reduced endospore (HARRIS 1986, 1995). The latter separate the genus from the similar *Pseudopyrenula*. Harris (1986) reported two further species from Bahia: *P. albidum* (Müll. Arg.) R. C. Harris and *P. catapastum* (Nyl.) R. C. Harris.

Polymeridium proponens (Nyl.) R. C. Harris

Specimen examined. PERNAMBUCO: Bonito, Parque Municipal de Bonito, 8° 28' S, 35°43' W, Brejo de Altitude (high altitude rainforest), 800 m, *Cáceres & Lücking 00-0322* (B-600124079, F).

Porina Müll. Arg. (Porinaceae)

Notes. Porina was long time considered as a prototype of perithecial lichens and as such related to perithecial fungi including Sphaeriales and other groups (HENSSEN & JAHNS 1974). However, a recent phylogenetic study showed the genus to belong in Ostropales s.lat., thus suggesting that the perithecia are derived via neotenic evolution from apothecia (GRUBE *et al.* 2004). *Porina* is here used in a wide sense, including all species with glabrous perithecia (MCCARTHY & MALCOLM 1997; MCCARTHY 2000, 2001, 2003).

Key to species of *Porina*

1a. Perithecia wall exposed, lacking crystallostratum and thallus layer 2
1b. Perithecia wall covered by crystallostratum and thallus layer 5

2a. Perithecia wall black..... 3
2b. Perithecia wall orange-red..... 4

3a. Ascospores 3-septate ..... ***P. ambigua***
3b. Ascospores 7-septate .....***P. cestrensis***

4a. Ascospores 5-septates; lichenicolous on *Porina* .....***P. epilucida***
4b. Ascospores 3-septate; lichenized.....***P. leptalea***

5a. Ascospores submuriform or muriform 6
5b. Ascospores transversely septate 7

6a. Ascospores submuriform, 50–70 × 15–17 µm .....***P. nuculastrum***
6b. Ascospores muriform, 80–125 × 25–30 µm.....***P. farinosa***

7a. Ascospores 7-septate only 8
7b. Ascospores 7–9 (–13)-septate..... 15

8a. Isidia present..... 9
8b. Isidia absent 10

9a. Prothallus dark, nitidous; ascospores 40–50 × 6–8 µm..... ***P. conspersa***
9b. Prothallus absent; ascospores 35–50 × 5–8 µm.....***P.scabrida***

10a. Ascospores 25–50(–55) µm long..... 11
10b. Ascospores (40–)45–70 µm long..... 13

11a. Prothallus absent; perithecia wart-shaped to subglobose, with red-brown spot .....***P. africana***
11b. Prothallus dark, nitidous; perithecia conical, with brown-black spot 12

12a. Ascospores 25–35 × 3–4 µm .....***P. curtula***
12b. Ascospores 40–50 × 5–6 µm ..... ***P. tetracerae***

13a. Prothallus absent; thallus verruculose, matt ..... ***P. nucula***
13b. Prothallus dark, nitidous; thallus smooth, nitidous 14

14a. Perithecia applanately conical, with red-brown spot.....***P. imitatrix***
14b. Perithecia lens-shaped, with brown-black spot ..... ***P. mastoidea***

15a. Ascospores 7–9-septate, 45–60 µm long 16
15b. Ascospores 7–13-septate, (50–)65–100 µm long 17

16a. Ascospores 40–45 × 5–6 µm; perithecia wart-shaped to subglobose .... ***P. simulans***
16b. Ascospores 40–60 × 6–10 µm; perithecia lens-shaped to wart-shaped.. ..... ***P. limitata***

17a. Prothallus dark, nitidous; perithecia lens-shaped to wart-shaped, with brown-black spot; ascospores 7–13-septate, 65–85 × 12–15 µm..... ..... ***P. internigrans***
17b. Prothallus absent..... 18

18a. Perithecia lens-shaped; ascospores 7–11-septate, 70–100 × 12–15 µm. ..... ***P.*** aff. ***internigrans***
18b. Perithecia wart-shaped, verruculose 19

19a. Ascospores 7–13-septate, 50–100 × 7–13 µm..... ***P. guaranitica***
19b. Ascospores 9–11-septate, 50–75 × 10–12 µm..... ***P. rudiuscula***

Porina africana Müll. Arg. (FIG. 28A)

Specimens examined. ALAGOAS: Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (closed forest), 50 m, *Cáceres & Lücking 01-0104* (F), *M. Cáceres s.n.* (F). PERNAMBUCO: Igarassu, Refúgio Ecológico Charles Darwin, 7° 50' S, 34° 54' W, Mata Atlântica (closed forest), 20 m, *Cáceres & Lücking 00-0419* (URM). SERGIPE: Santa Luzia, Private property, 11° 19' S, 37° 27' W, Mata Atlântica (closed forest), *Cáceres & Lücking 00-0887* (ABL, F, URM), *00-0890* (B-600124225, F), *00-0894* (B-600124228), *00-0883* (B-600124235), *00-0829* (F), *00-0852* (F, URM), *00-0856* (F), *00-0892* (F), *00-0851a* (URM).

Porina ambigua Malme

Specimen examined. PERNAMBUCO: Cabo de Santo Agostinho, Reserva Ecológica de Gurjaú, 8° 19' S, 35° 04' W, Mata Atlântica (closed forest), 30 m, *Cáceres & Lücking 00-0251* (ABL, B-600124166, F).

Porina cestrensis (Michener) Müll. Arg.

Specimens examined. ALAGOAS: Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (closed forest), 50 m, *Cáceres & Lücking 01-0049* (B-600124137). PERNAMBUCO: Bonito, Parque Municipal de Bonito, 8° 28' S, 35°43' W, Brejo de Altitude (high altitude rainforest), 800 m, *Cáceres & Lücking 00-0271* (F).

Porina conspersa Malme (FIG. 28B)

Specimens examined. ALAGOAS: Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (closed forest), 50 m, *Cáceres & Lücking 01-0554b* (URM). Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (forest along main trail), 50 m, *M. Cáceres A01-010* (URM), *A01-018* (F), *A05-044* (B), *A08-060* (URM), *A08-062* (B, F), *A09-073* (URM), *A09-082* (F, URM), *A09-085* (URM), *A09-090c* (F), *A10-095* (B), *A10-097* (B), *A10-098c* (F), *A11-103* (URM), *A11-104* (URM), *A11-105a* (URM), *A11-107* (B), *A16-146* (B, F), *A16-148* (B, F), *A17-151a* (F), *A17-160* (B), *A18-165a* (B), *A18-169* (F), *A19-169a* (F), *A20-169a* (F), *A21-169a* (F), *A22-169* (B, F), *A24-169a* (F), *A24-205* (URM), *A26-228* (URM), *A27-169a* (F), *A28-169a* (F), *A28-240b* (F), *A34-262b* (F), *A36-169a* (F), *A36-275* (F), *A36-277c* (F), *A36-280c* (URM), *A37-275* (F), *A37-285b* (URM), *A37-288* (F), *A41-169a* (F), *A42-169a* (F), *A42-324e* (F), *A42-330b* (URM), *A45-367c* (F), *A46-426c* (F), *A46-435b* (URM).

Porina curtula Malme (FIG. 28C)

Notes. This taxon was synonymized with the saxicolous *Porina subinterstes* (Nyl.) Müll. Arg. by MCCARTHY (2004; LÜCKING & VĚZDA 1998), but re-examination of the type material of both species, and evidence from other collections suggests that the corticolous and foliicolous specimens are specifically distinct.

Specimens examined. ALAGOAS: Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (closed forest), 50 m, *Cáceres & Lücking 01-0550* (B, F, URM), *Cáceres s.n.* (B, F), *Cáceres & Lücking 01-0554a* (URM). Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (forest along main trail), 50 m, *Cáceres A06-048a* (F), *A06-050b* (F), *A23-197* (B, F).

Porina epilucida Sipman

Specimen examined. SERGIPE: Santa Luzia, Private property, 11° 19' S, 37° 27' W, Mata Atlântica (closed forest), *Cáceres & Lücking 00-0857* (F).

Porina farinosa C. Knight (FIG. 28D)

Specimens examined. ALAGOAS: Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (closed forest), 50 m, *Cáceres & Lücking 01-0071* (F), *01-0539* (F), *01-0053a* (URM).

Porina guaranitica Malme (FIG. 28E)

Specimens examined. PERNAMBUCO: Caruaru, Brejo dos Cavalos, 8° 20' S, 35° 58' W, Brejo de Altitude (high altitude rainforest), 800–900 m, *Cáceres & Lücking 00-613* (ABL, B-600124168, F), *00-564* (B-600124169, F, URM).

Porina imitatrix Müll. Arg. (FIG. 28F)

Specimens examined. PERNAMBUCO: Caruaru, Brejo dos Cavalos, 8° 20' S, 35° 58' W, Brejo de Altitude (high altitude rainforest), 800–900 m, *Cáceres & Lücking 00-0562* (F), *00-0565* (F), *00-0566* (F, URM). Igarassu, Refúgio Ecológico Charles Darwin, 7° 50' S, 34° 54' W, Mata Atlântica (closed forest), 20 m, *Cáceres & Lücking 00-0434* (B-600124227, F). SERGIPE: Areia Branca, Reserva Ecológica Serra de Itabaiana, 10° 45' S, 37° 20' W, Mata Atlântica (closed forest), 500 m, *M. Cáceres 2081* (F). Ribeira, Mata Atlântica, *M. Cáceres 2025* (F).

Porina internigrans (Nyl.) Müll. Arg.

Specimens examined. ALAGOAS: Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (closed forest), 50 m, *Cáceres & Lücking 01-0503* (F), *01-0551* (F). Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (forest along main trail), 50 m, *M. Cáceres A09-084a* (B, F), *A28-239* (F), *A33-261* (URM), *A36-278* (F, URM), *A36-280b* (URM). PERNAMBUCO: Cabo de Santo Agostinho, Reserva Ecológica de Gurjaú, 8° 19' S, 35° 04' W, Mata Atlântica (closed forest), 30 m, *Cáceres & Lücking 00-0176* (ABL), *00-0174* (B-600124167), *00-0252* (B-600124171, URM), *00-0171* (B-600124172), *00-0173* (F).

Porina aff. ***internigrans*** (Nyl.) Müll. Arg.

Notes. This species is close to *Porina internigrans* but differs by its more greenish, opaque thallus with roughened, whitish surface around the ostiole and in parts of the thallus, resembling tiny pseudocyphellae.

Specimens examined. ALAGOAS: Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (forest along main trail), 50 m, *M. Cáceres A03-022* (F). PERNAMBUCO: Bonito, Parque Municipal de Bonito, 8° 28' S, 35°43' W, Brejo de Altitude (high altitude rainforest), 800 m, *Cáceres & Lücking 00-0308* (B-600124164, F), *00-0298* (F, URM). Igarassu, Refúgio Ecológico Charles Darwin, 7° 50' S, 34° 54' W, Mata Atlântica (closed forest), 20 m, *Cáceres & Lücking 00-0415* (F).

Porina leptalea (Durieau & Mont.) A. L. Sm.

Specimens examined. PERNAMBUCO: Cabo de Santo Agostinho, Reserva Ecológica de Gurjaú, 8° 19' S, 35° 04' W, Mata Atlântica (closed forest), 30 m, *Cáceres & Lücking 00-0185* (F).

Porina limitata C. Knight

Specimens examined. ALAGOAS: Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (forest along main trail), 50 m, *M. Cáceres A17-151b* (F), *A42-324d* (F).

Porina mastoidea (Ach.) Müll. Arg. (FIG. 28G)

Specimens examined. ALAGOAS: Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (closed forest), 50 m, *Cáceres &*

Lücking 01-0035 (B-600124135), *M. Cáceres 2007* (B-600124241, F), *Cáceres & Lücking 01-0039* (F), *01-0061* (F), *01-0157a* (F), *01-0036* (URM), *01-0043* (URM)., *01-0077* (URM), *01-0110* (URM), *01-0111* (URM), *01-0124* (URM). Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (forest along main trail), 50 m, *M. Cáceres A09-081a* (B), *A09-089* (F, URM), *A09-090b* (F), *A20-182* (URM), *A24-199* (URM), *A41-321a* (F), *A42-321* (F), *A42-331* (B). PERNAMBUCO: Cabo de Santo Agostinho, Reserva Ecológica de Gurjaú (Barragem), 8° 19' S, 35° 04' W, Mata Atlântica (closed forest), 30 m, Mata Atlântica, *Cáceres & Lücking 98-s.n.* (F). Caruaru, Brejo dos Cavalos, 8° 20' S, 35° 58' W, Brejo de Altitude (high altitude rainforest), 800–900 m, *Cáceres & Lücking 00-0561* (B-600124081, F), *00-0568* (F). RIO GRANDE DO NORTE: Baía Formosa, Reserva Particular do Patrimônio Natural (RPPN) Mata Estrela Senador Antônio Farias, 06° 22' S, 35° 01' W, Mata Atlântica (closed forest), 0 m, *M. Cáceres 01-0160* (B-600124244, F, URM), *01-0161* (B-600124253, duplicate, F, URM), *01-0167* (F). SERGIPE: Itabaiana, Fazenda São Jose, 10° 45' S, 37° 20' W, Mata Atlântica (closed forest), 500 m, *M. Cáceres 2155* (B, URM). Santa Luzia, Private property, 11° 19' S, 37° 27' W, Mata Atlântica (closed forest), *Cáceres & Lücking 00-0835* (F, URM), *00-0836* (F), *00-0890b* (F), *00-0892* (F), *00-0851b* (URM). Ribeira, Mata Atlântica, *Cáceres 2044* (F), *2046* (F), *2045* (URM), *2049* (URM).

Porina nucula Ach.

Specimens examined. ALAGOAS: Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (forest along main trail), 50 m, *M. Cáceres A17-151d* (F), *A24-198a* (F), *A46-436* (URM). PERNAMBUCO: Bonito, Parque Municipal de Bonito, 8° 28' S, 35°43' W, Brejo de Altitude (high altitude rainforest), 800 m, *Cáceres & Lücking 00-0323* (B-600124082). Caruaru, Brejo dos Cavalos, 8° 20' S, 35° 58' W, Brejo de Altitude (high altitude rainforest), 800–900 m, *Cáceres & Lücking 00-0541* (B-600124083), *00-0563* (B-600124084, F, URM), *00-0540* (F). Igarassu, Refúgio Ecológico Charles Darwin, 7° 50' S, 34° 54' W, Mata Atlântica (closed forest), 20 m, *Cáceres & Lücking 00-0418* (URM). SERGIPE: Areia Branca, Reserva Ecológica Serra de Itabaiana, 10° 45' S, 37° 20' W, Mata Atlântica (closed forest), 500 m, *M. Cáceres 2078* (F).

Porina nuculastrum (Müll. Arg.) R. C. Harris

Specimens examined. ALAGOAS: Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (closed forest), 50 m, *Cáceres & Lücking 01-0458* (B-600124257), *01-0034* (F). Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (forest along main trail), 50 m, *M. Cáceres A04-034a* (F), *A46-430* (F). PERNAMBUCO: Bonito, Parque Municipal de Bonito, 8° 28' S, 35°43' W, Brejo de Altitude (high altitude rainforest), 800 m, *Cáceres & Lücking 00-0298* (B-600124110, URM). Cabo de Santo Agostinho, Reserva Ecológica de Gurjaú, 8° 19' S, 35° 04' W, Mata Atlântica (closed forest), 30 m, *Cáceres & Lücking 00-0175* (ABL, B-600124109, F). São Lourenço da Mata, Estação Ecológica de Tapacurá, 8° 02' S, 35° 09' W, Agreste (open dry forest), 100 m, *Cáceres & Lücking 98-0253* (F). SERGIPE: Areia Branca, Reserva Ecológica Serra de Itabaiana, 10° 45' S, 37° 20' W, Mata Atlântica (closed forest), 500 m, *M. Cáceres 2081* (F).

Porina rudiuscula (Nyl.) Müll. Arg.

Specimens examined. ALAGOAS: Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (closed forest), 50 m, *Cáceres & Lücking 01-0060* (F). PERNAMBUCO: Caruaru, Brejo dos Cavalos, 8° 20' S, 35° 58' W, Brejo de Altitude (high altitude rainforest), 800–900 m, *Cáceres & Lücking 00-0664c* (F).

Porina scabrida R. C. Harris (FIG. 28H)

Specimens examined. ALAGOAS: Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (closed forest), 50 m, *Cáceres & Lücking 01-0541b* (F). Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (forest along main trail), 50 m, *Cáceres A08-064* (F). PERNAMBUCO: Cabo de Santo Agostinho, Reserva Ecológica de Gurjaú, 8° 19' S, 35° 04' W, Mata Atlântica (closed forest), 30 m, *Cáceres & Lücking 00-0170* (B-600124165), *00-0177a* (F).

Porina simulans Müll. Arg.

Specimen examined. ALAGOAS: Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (forest along main trail), 50 m, *M. Cáceres A44-cortex* (F).

Porina tetracerae (Afz. in Ach.) Müll. Arg.

Specimens examined. ALAGOAS: Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (closed forest), 50 m, *Cáceres & Lücking 01-0113* (B-600124239), *01-0089* (B-600124245), *01-0552* (F), *01-0053b* (URM), *01-0088* (URM). Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (forest along main trail), 50 m, *M. Cáceres A05-040* (URM), *A06-049* (B, F, URM), *A46-430* (URM), *A46-435a* (URM). PERNAMBUCO: Cabo de Santo Agostinho, Reserva Ecológica de Gurjaú, 8° 19' S, 35° 04' W, Mata Atlântica (closed forest), 30 m, *Cáceres & Lücking 00-0177b* (F). Caruaru, Brejo dos Cavalos, 8° 20' S, 35° 58' W, Brejo de Altitude (high altitude rainforest), 800–900 m, *Cáceres & Lücking 00-0630* (F), *00-0567* (URM). Igarassu, Refúgio Ecológico Charles Darwin, 7° 50' S, 34° 54' W, Mata Atlântica (closed forest), 20 m, *Cáceres & Lücking 00-0416* (F, URM), *00-0417* (F). RIO GRANDE DO NORTE: Baía Formosa, Reserva Particular do Patrimônio Natural (RPPN) Mata Estrela Senador Antônio Farias, 06° 22' S, 35° 01' W, Mata Atlântica (closed forest), 0 m, *M. Cáceres 01-0176* (B-600124242, F), *01-0166* (B-600124254, F, URM), *01-0183* (URM).

Pseudopyrenula Müll. Arg. (Trypetheliaceae)

Notes. Pseudopyrenula is superficially similar to *Anisomeridium* and *Strigula* but differs by its *Trypethelium*-type hamathecium and ascospores (with thickened endospore). The related *Polymeridium* can be distinguished by its more thin-walled ascospores (HARRIS 1986, 1995). *Pseudopyrenula diluta* (Fée) Müll. Arg. might also occur in the area (HARRIS 1986).

Key to species of *Pseudopyrenula*

1a. Thallus white ..... ***P. subnudata***
1b. Thallus olive-brown..... ***P.*** spec.

Pseudopyrenula subnudata Müll. Arg.

Specimens examined. PERNAMBUCO: Caruaru, Brejo dos Cavalos, 8° 20' S, 35° 58' W, Brejo de Altitude (high altitude rainforest), 800–900 m, *Cáceres & Lücking 00-0559* (B-600124112, URM). Igarassu, Refúgio Ecológico Charles Darwin, 7° 50' S, 34° 54' W, Mata Atlântica (closed forest), 20 m, *Cáceres & Lücking 00-0447* (F). SERGIPE: Santa Luzia, Private property, 11° 19' S, 37° 27' W, Mata Atlântica (closed forest), *Cáceres & Lücking 00-0893* (B-600124229, F).

Pseudopyrenula spec.

Notes. The material differs from the preceeding species chiefly by its olive-brown thallus, very similar to species in *Pyrenula*, such as *P. mamillana*.

Specimen examined. PERNAMBUCO: Igarassu, Refúgio Ecológico Charles Darwin, 7° 50' S, 34° 54' W, Mata Atlântica (closed forest), 20 m, *Cáceres & Lücking 00-0444* (F).

Pyrenula Ach. (Pyrenulaceae)

Notes. Pyrenula is among the most common and widespread genera among tropical rainforest microlichens. Unfortunately, no monographic treatment exists for tropical regions, but since many species extent their range into subtropical areas of North America, the treatments by HARRIS (1989, 1995) are very helpful to identify species.

Key to species of *Pyrenula*

1a. Ascospores transversely septate 2
1b. Ascospores (sub)muriform 15

2a. Perithecia laterally fused and/or aggregate in pseudostromata 3
2b. Perithecia solitary 5

3a. Perithecia with ostiole lateral and fused..... ***P. septicollaris***
3b. Perithecia laterally fused and aggregate but with ostioles apical and separate 4

4a. Perithecial aggregates small, irregular ..... ***P. anomala***
4b. Perithecial aggregates forming large, black, arthonoid plates..... ..... ***P. lineatostroma***

5a. Ostioles lateral ..... ***P. microtheca***

5b. Ostioles apical 6

6a. Ascospores mostly more than 20 μm long 7
6b. Ascospores mostly less than 20 μm long 11

7a. Thallus near and above perithecia red, K+ purple..... ***P. cruenta***
7b. Thallus lacking red pigment 8

8a. Ascospores very large (over 50 μm long), with terminal cells directly against wall..... ***P. prelucida***
8b. Ascospores smaller (less than 50 μm long), with terminal cells separated from wall by endospore 9

9a. Postmature ascospores empty, collapsing; thallus lacking white maculae ..... ***P. macrocarpa***
9b. Postmature ascospores with oily substance; thallus with white maculae 10

10a. Oily substance red ..... ***P. concatervans***
10a. Oily substance colorless ..... ***P. quassiaecola***

11a. Thallus UV+ yellow-orange; perithecia covered by thallus almost up to ostiole ..... ***P. micromma***
11b. Thallus UV–; perithecia exposed, grey-black 12

12a. Ascospores with terminal cells directly against wall..... ***P. nitidula***
12b. Ascospores with terminal cells separated from wall by endospore.... 13

13a. Perithecia 0.3–0.6 mm in diam., often crowded..... ***P. aspistea***
13b. Perithecia 0.6–1.5 mm in diam., scattered..... 14

14a. Hymenium inspersed; thallus and perithecia often nitidous..... ..... ***P. mamillana***
14b. Hymenium clear; thallus and perithecia mostly matt ..... ***P. santensis***

15a. Thallus orange to red, K+ purple..... 16
15b. Thallus lacking orange or red pigment..... 17

16a. Thallus red; ascospores 30–45 × 15–20 μm ..... ***P. cruentata***
16b. Thallus orange; ascospores 15–25 × 9–13 μm ..... ***P. ochraceoflava***

17a. Ostioles lateral and several perithecia with ostioles fused; ascospores 30–45 × 13–18 μm..... ***P. astroidea***

17b. Ostioles apical and separate and perithecia solitary; ascospores 40–65 × 17–24 µm..... 18

18a. Postmature ascospores with red oily substance; ascospores 40–55 × 17–22 µm..... ***P. macularis***
18b. Postmature ascospores empty, collapsing; ascospores 50–65 × 18–24 µm.....***P. pyrenuloides***

Pyrenula anomala (Ach.) Vain. (FIG. 29A)

Specimens examined. ALAGOAS: Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (closed forest), 50 m, *Cáceres & Lücking 01-0003* (B-600124141), *01-0056* (B-600124142, F, URM), *01-0003* (F, URM), *01-0515* (URM), *01-0540* (URM).

Pyrenula aspistea (Ach.) Ach. (FIG. 29B)

Specimens examined. SERGIPE: Santa Luzia, Private property, 11° 19' S, 37° 27' W, Mata Atlântica (closed forest), *Cáceres & Lücking 00-0884* (B-600124234, F), *00-0885* (F). Ribeira, Mata Atlântica, *M. Cáceres 2030b* (F).

Pyrenula astroidea (Fée) R. C. Harris (FIG. 29C)

Specimens examined. PERNAMBUCO: Cabo de Santo Agostinho, Reserva Ecológica de Gurjaú, 8° 19' S, 35° 04' W, secondary vegetation (open area), 30 m, *Cáceres & Lücking 00-0253* (F). SERGIPE: Itabaiana, Fazenda São Jose, 10° 45' S, 37° 20' W, Mata Atlântica (closed forest), 500 m, *M. Cáceres 2061* (URM).

Pyrenula concatervans (Nyl.) R. C. Harris (FIG. 29D)

Specimens examined. PERNAMBUCO: Cabo de Santo Agostinho, Reserva Ecológica de Gurjaú, 8° 19' S, 35° 04' W, secondary vegetation (open area), 30 m, *Cáceres & Lücking 00-0261* (B-600124117, URM), *00-0181* (URM). Caruaru, Instituto Pernambucano de Pesquisas Agropecuárias (IPA), 8° 17' S, 35° 58' W, Caatinga (open thornbush), 500–600 m, *Cáceres & Lücking 00-0052* (B-600124115), *00-0039* (F), *00-0049* (F).

Pyrenula cruenta (Mont.) Vainio (FIG. 29E)

Specimens examined. SERGIPE: Santa Luzia, Private property, 11° 19' S, 37° 27' W, Mata Atlântica (closed forest), *Cáceres & Lücking 00-0886* (F).

Pyrenula cruentata (Müll. Arg.) R. C. Harris

Specimens examined. ALAGOAS: Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (closed forest), 50 m, *Cáceres & Lücking 01-0004* (B, F, URM).

Pyrenula lineatostroma Aptroot

Specimens examined. ALAGOAS: Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (forest along main trail), 50 m, *M. Cáceres A46-425* (F), *A47-446* (F).

Pyrenula macrocarpa A. Massal.

Specimen examined. ALAGOAS: Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (forest along main trail), 50 m, *M. Cáceres A37-cortex* (F).

Pyrenula macularis (Zahlbr.) R. C. Harris (FIG. 29F)

Specimens examined. PERNAMBUCO: São Lourenço da Mata, Estação Ecológica de Tapacurá, 8° 02' S, 35° 09' W, Agreste (open dry forest), 100 m, *Cáceres & Lücking 98-0601* (B-600124280, F), *98-0600* (F).

Pyrenula mamillana (Ach.) Trevis. (FIG. 29G)

Specimens examined. ALAGOAS: Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (closed forest), 50 m, *Cáceres & Lücking 01-0068* (F), *01-0542* (F), *M. Cáceres 2072* (F), *Cáceres & Lücking 01-0028* (URM), *01-0055* (URM). Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (forest along main trail), 50 m, *M. Cáceres A12-116* (B, F), *A19-173* (B, F), *A26-221* (URM), *A36-279* (B, URM), *A42-330a* (URM), *A46-414* (URM), *A46-428a* (F). PERNAMBUCO: Cabo de Santo Agostinho, Reserva Ecológica de Gurjaú, 8° 19' S, 35° 04' W, Mata Atlântica (closed forest), 30 m, *Cáceres & Lücking 00-0180* (ABL, F), *00-0349* (B-600124116). Igarassu, Refúgio Ecológico Charles Darwin, 7° 50' S, 34° 54' W, Mata Atlântica (closed forest), 20 m, *Cáceres & Lücking 00-0449* (B-600124118, URM), *00-0450* (B-600124119), *00-0451* (B-600124120, F), *00-0454* (B-600124121), *00-0448* (F), *00-0452* (F), *00-0453* (URM). SERGIPE: Santa Luzia, Private property, 11° 19' S, 37° 27' W, Mata Atlântica (closed forest), *Cáceres & Lücking 00-0897* (B-600124231), *00-0833* (F).

Pyrenula micromma (Mont.) Trevis. (FIG. 29H)

Specimen examined. PERNAMBUCO: Cabo de Santo Agostinho, Reserva Ecológica de Gurjaú, 8° 19' S, 35° 04' W, Mata Atlântica (closed forest), 30 m, *Cáceres & Lücking 00-0172* (ABL, B-600124122, F).

Pyrenula mycrotheca R. C. Harris (FIG. 30A)

Specimen examined. ALAGOAS: Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (forest along main trail), 50 m, *M. Cáceres A04-026* (F).

Pyrenula nitidula (Bresadola) R. C. Harris (FIG. 30B)

Specimens examined. ALAGOAS: Barra de São Miguel, Reserva Particular do Patrimônio Natural (RPPN) Rosa do Sol, 09° 51' S, 35° 53' W, Mata Atlântica (closed forest), 50 m, *M. Cáceres 01-0147* (F). Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (closed forest), 50 m, *Cáceres & Lücking 01-0065* (F, URM). Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (forest along main trail), 50 m, *M. Cáceres A21-185a* (B, F), *A35-270b* (F), *A46-417d* (F), *A46-422* (URM), *A46-427a* (URM), *A47-445d* (F). PERNAMBUCO: Cabo de Santo Agostinho, Reserva Ecológica de Gurjaú, 8° 19' S, 35° 04' W, secondary vegetation (open area), 30 m, *Cáceres & Lücking 00-0254* (ABL, B-600124124, F), *00-0243* (B-600124123). São Lourenço da Mata, Estação Ecológica de Tapacurá, 8° 02' S, 35° 09' W, Agreste (open dry forest), 100 m, *Cáceres & Lücking 98-0514* (F). SERGIPE: Ribeira, Mata Atlântica, *M. Cáceres 2064* (F).

Pyrenula ochraceoflava (Nyl.) R.C. Harris (FIG. 30C)

Specimens examined. ALAGOAS: Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (closed forest), 50 m, *M. Cáceres s.n.* (F). PERNAMBUCO: Cabo de Santo Agostinho, Reserva Ecológica de Gurjaú, 8° 19' S, 35° 04' W, secondary vegetation (open area), 30 m, *Cáceres & Lücking 00-0227* (B-600124127), *00-0262* (URM). Caruaru, Instituto Pernambucano de Pesquisas Agropecuárias (IPA), 8° 17' S, 35° 58' W, Caatinga (open thornbush), 500–600 m, *Cáceres & Lücking 00-0035* (B-600124125), *00-0034a* (F). Caruaru, Instituto Pernambucano de Pesquisas Agropecuárias (IPA), 8° 17' S, 35° 58' W, secondary vegetation (open area in front of main building), 500–600 m, *Cáceres & Lücking 00-0112* (F). São Lourenço da Mata, Estação Ecológica de Tapacurá, 8° 02' S, 35° 09' W, Agreste (open dry forest), 100 m, *Cáceres & Lücking 98-0513* (B), *98-0263* (F), *98-0513* (F, URM).

Pyrenula prelucida (Mont.) Trevis. (FIG. 30D)

Specimens examined. PERNAMBUCO: Cabo de Santo Agostinho, Reserva Ecológica de Gurjaú, 8° 19' S, 35° 04' W, secondary vegetation (open area), 30 m, *Cáceres & Lücking 00-0255* (B-600124128, F, URM), *00-0258* (B-600124129), *00-0257* (F, URM).

Pyrenula pyrenuloides (Mont.) R. C. Harris

Specimens examined. ALAGOAS: Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (forest along main trail), 50 m, *M. Cáceres A37-cortex* (F). PERNAMBUCO: Cabo de Santo Agostinho, Reserva Ecológica de Gurjaú, 8° 19' S, 35° 04' W, secondary vegetation (open area), 30 m, *Cáceres & Lücking 00-0256* (B-600124130, F), *00-0260* (URM). SERGIPE: Santa Luzia, Private property, 11° 19' S, 37° 27' W, Mata Atlântica (closed forest), *Cáceres & Lücking 00-0891* (B-600124232).

Pyrenula quassiaecola Fée (FIG. 30E)

Specimens examined. PERNAMBUCO: Caruaru, Instituto Pernambucano de Pesquisas Agropecuárias (IPA), 8° 17' S, 35° 58' W, Caatinga (open thornbush), 500–600 m, *Cáceres & Lücking 00-0050* (B-600124131, F), *00-0047* (F), *00-0044* (URM), *00-0050* (URM), *00-0051* (URM). RIO GRANDE DO NORTE: Baía Formosa, Reserva Particular do Patrimônio Natural (RPPN) Mata Estrela Senador Antônio Farias, 06° 22' S, 35° 01' W, Mata Atlântica (closed forest), 0 m, *M. Cáceres 01-0175* (F).

Pyrenula santensis (Nyl.) Müll. Arg. (FIG. 30F)

Specimens examined. PERNAMBUCO: Cabo de Santo Agostinho, Reserva Ecológica de Gurjaú, 8° 19' S, 35° 04' W, secondary vegetation (open area), 30 m, *Cáceres & Lücking 00-0239* (B-600124222, F). Caruaru, Brejo dos Cavalos, 8° 20' S, 35° 58' W, Brejo de Altitude (high altitude rainforest), 800–900 m, *Cáceres & Lücking 00-0539* (B-600124221).

Pyrenula septicollaris (Eschw.) R. C. Harris (FIG. 30G)

Specimen examined. PERNAMBUCO: Caruaru, Instituto Pernambucano de Pesquisas Agropecuárias (IPA), 8° 17' S, 35° 58' W, Caatinga (open thornbush), 500–600 m, *Cáceres & Lücking 00-0046* (B-600124220, F).

Pyrgillus Nyl. (Pyrenulaceae)

Notes. Although producing mazaedioid ascomata, *Pyrgillus* has been shown to belong in Pyrenulaceae, and the mazaedia are thus derived from perithecia (APTROOT 1991; HARRIS 1989; TIBELL 1996; LUMBSCH *et al.* 2004). Indeed, the ascospores of Pyrgillus resemble those of certain *Pyrenula* species. There seems to be only one common neotropical species.

Pyrgillus javanicus (Ach.) Vain. (FIG. 30H)

Specimens examined. ALAGOAS: Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (closed forest), 50 m, *Cáceres & Lücking 01-0026* (B-600124136, F, URM), *01-0105* (B-600124139), *01-0050* (B-600124176, F), *01-0602* (URM). Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (forest along main trail), 50 m, *Cáceres A11-105b* (URM), *A11-106* (B, URM), *A37-281b* (URM), *A37-282* (B, F), *A37-287a* (F). SERGIPE: Itabaiana, Fazenda São Jose, 10° 45' S, 37° 20' W, Mata Atlântica (closed forest), 500 m, *Cáceres 2052* (F, URM).

Pyrrhospora Körb. (Lecanoraceae)

Notes. Pyrrhospora is among the most common elements of tropical microlichen communities in exposed habitats, and thus far, the bulk of the species was identified as *P. russula*. However, a recent revision of the group (KALB, pers. comm. 2006) showed that at least two species are involved with different chemistry, and the more common taxon is now called *P. haematites*. In the present material, both species show ecological differentiation; while *P. haematites* is dominant in exposed situation in the Caatinga*, P. russula* is apparently restricted to the rainforest canopy.

Key to species of *Pyrrhospora*

1a. Norstictic acid..... ***P. haematites***

1b. Fumarprotocetraric acid.....***P. russula***

Pyrrhospora haematites (Fée) Kalb (FIG. 31A)

Specimens examined. PERNAMBUCO: Caruaru, Brejo dos Cavalos, 8° 20' S, 35° 58' W, secondary vegetation (fence posts), 800–900 m, *Cáceres & Lücking 00-0805a* (B-600124145), *00-0802* (B-600124155), *00-0807a* (B-600124157), *00-0801a* (F), *00-0803a* (F), *00-0806a* (F), *00-0808a* (F), *00-0804* (URM), *00-0809* (URM). Caruaru, Instituto Pernambucano de Pesquisas Agropecuárias (IPA), 8° 17' S, 35° 58' W, Caatinga (open thornbush), 500–600 m, *Cáceres & Lücking 00-0088* (B-600124156, duplicate, F, URM), *00-0089* (B-600124160), *00-0083a* (F), *00-0087* (URM), *00-0102* (URM). Caruaru, Instituto Pernambucano de Pesquisas Agropecuárias (IPA), 8° 17' S, 35° 58' W, secondary vegetation (open area in front of main building), 500–600 m, *Cáceres & Lücking 00-0121a* (B-600124162), *00-0118* (F), *00-0119* (F), *00-0120a* (F), *00-0125* (URM). Garanhuns, secondary Caatinga vegetation, *Cáceres & Lücking 98-0500c* (F), *98-0507* (URM), *98-0515* (URM). SERGIPE: Gararu, 9° 58' S, 37° 54' W, Caatinga (thornbush), 0–100 m, *M. Cáceres 2125b* (F), *2115a* (URM), *2090* (F), *2091* (F), *2092* (F), *2096* (F), *2101* (F), *2102* (F), *2104* (F), *2110* (F), *2110* (F), *2118* (F), *2119* (F), *2120* (F), *2129* (F), *2130* (F), *2131* (F), *2132* (F), *2138* (F), *2142* (F), *2144* (F), *2146* (F), *2147* (F), *2148* (F), *2150* (F).

Pyrrhospora russula (Ach.) Hafellner

Specimens examined. PERNAMBUCO: Caruaru, Brejo dos Cavalos, 8° 20' S, 35° 58' W, Brejo de Altitude (high altitude rainforest), 800–900 m, *Cáceres & Lücking 00-0657* (B-600124159, F).

Pyxine Fr. (Physciaceae)

Notes. *Pyxine* was monographed for Brazil by KALB (1987), who listed 26 taxa for the country. Although *Pyxine* is commonly found in more exposed and drier situations, only one species was detected in the present material. However, several species are known from the adjacent states of Piauí and Bahia (KALB 1987); *P. cocoes* (Sw.) Nyl., *P. daedalea* Krog & R. Sant., *P. endolutea* Kalb, *P. oscurascens* Malme, and *P. schechingeri* Kalb.

Pyxine berteriana (Fée) Imsh.

Specimens examined. PERNAMBUCO: Caruaru, Instituto Pernambucano de Pesquisas Agropecuárias (IPA), 8° 17' S, 35° 58' W, Caatinga (open thornbush), 500–600 m, *Cáceres & Lücking 00-0020a* (B-600124271). SERGIPE: Gararu, 9° 58' S, 37° 54' W, Caatinga (thornbush), 0–100 m, *M. Cáceres 2128* (B, F, URM).

Ramonia Stizenb. (Gyalectaceae)

Notes. *Ramonia* is a genus of inconspicuous, easily overlooked lichens resembling species of *Asconditella* and *Stictis* at first glance (VĚZDA 1973). While the latter two differ by their chlorococcoid photobiont and filiform

ascospores, respectively, the superficially similar genera *Gyalecta* and *Cryptolechia* differ by their sessile rather than immersed apothecia.

Ramonia intermedia Kalb (FIG. 31B)

Specimens examined. ALAGOAS: Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (forest along main trail), 50 m, *M. Cáceres A33-cortex* (F). PERNAMBUCO: Cabo de Santo Agostinho, Reserva Ecológica de Gurjaú, 8° 19' S, 35° 04' W, Mata Atlântica (closed forest), 30 m, *Cáceres & Lücking 00-0206* (B-600124270), *00-0203* (F), *00-0220b* (F). RIO GRANDE DO NORTE: Baía Formosa, Reserva Particular do Patrimônio Natural (RPPN) Mata Estrela Senador Antônio Farias, 06° 22' S, 35° 01' W, Mata Atlântica (closed forest), 0 m, *M. Cáceres 01-0189b* (F).

Rinodina (Ach.) Gray (Physciaceae)

Notes. Species of *Rinodina* can be recognized by their crustose to sometimes microsquamulose thallus and lecanorine apothecia producing dark brown ascospores.

Rinodina spec.

Specimen examined. SERGIPE: Itabi, Private property, 10° 06' S, 37° 54' W, Caatinga (thornbush), 100 m, *M. Cáceres 2177* (F, URM).

Sagenidiopsis R.W. Rogers & Hafellner (Arthoniaceae)

Notes. Lichens of the genus *Sagenidiopsis* are easily recognized by their byssoid thallus (similar to *Dichosporidium*) and their very large apothecioid ascomata (ROGERS & HAFELLNER 1987; EGEA *et al.* 1995; GRUBE 1998). The species listed below seems to be rare but produced unusually large, very conspicuous thalli on several trees where it was found.

Sagenidiopsis undulata (Fée) Egea, Tehler, Torrente & Sipman (FIG. 31C–D)

Specimen examined. PERNAMBUCO: Bonito, Parque Municipal de Bonito, 8° 28' S, 35°43' W, Brejo de Altitude (high altitude rainforest), 800 m, *Cáceres & Lücking 00-0265* (F, URM).

Sarcographa Fée (Graphidaceae)

Notes. Sarcographa is a characteristic element of tropical lowland microlichen communities in exposed situations, such as the forest canopy or the bark of exposed trees. The species are recognized by their stromatic, often secondarily divided ascomata in combination with a *Phaeographis*-type hymenium and ascospores (STAIGER 2002). *Leiorreuma* is similar in apothe-

cial anatomy but does not form stromata or secondarily divided discs and is more typical of tropical montane regions. Stromatic species of *Glyphis* can be distinguished by their colorless ascospores and clear hymenium.

Key to species of *Sarcographa*

1a. Lirellae for a long time solitary but eventually dividing through clusters of crystals; ascospores 7–13-septate, 25–50 µm long ..... ***S. ramificans***

1b. Lirellae in stellate clusters or stromatic and then discs soon divided by transverse splits; ascospores 3–5-septate, 12–25 µm long 2

2a. Lirellae in stellate clusters but not divided by splits; no substances ..... ***S. tricosa***

2b. Lirellae stromatic and soon subdivided by transverse splits; stictic acid and related substances 3

3a. Lirellae initially fissurine, only eventually becoming stromatic but sparsely subdivided only; thallus yellow-grey, uneven. ***S. fissurinoides***

3c. Lirellae stromatic from beginning, strongly subdivided; thallus dark green, smooth 4

4a. Stromata with distinct white margin higher than thallus; individual lirellae often separated by white pruinose sterile areas .. ***S. labyrinthica***

4b. Stromata with indistinct margin flush with thallus; individual lirellae usually completely covering stromata and lacking white pruinose sterile areas inbetween ..... ***S. fenicis***

Sarcographa fenicis (Vain.) Zahlbr.

Specimen examined. ALAGOAS: Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (closed forest), 50 m, *Cáceres & Lücking 01-0012* (F, URM).

Sarcographa fissurinoides Cáceres & Lücking **spec. nova** (FIG. 31E–F)

Sarcographa labyrinthica apotheciis iuvenibus fissurinis. differt. — Typus. ALAGOAS: Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (closed forest), 50 m, *Cáceres & Lücking 01-0527* (F, holotypus). — Paratypi. ALAGOAS: Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (closed forest), 50 m, *Cáceres & Lücking 01-0505* (F, URM), *01-0516* (B).

Description. Thallus crustose, corticolous, 50–100 mm across and 50–100 µm thick, continuous, smooth to uneven, with cartilaginous cortex, yellow-

grey. Photobiont *Trentepohlia*; cells angular-rounded, 6–10 µm diam. Lirellae in stromata, flexuose, stellately branched and usually leaving small interspaces, rarely secondarily dissected by transverse splits, immersed but flush with margin of stromata, the latter 2–5 mm across, with rounded to irregular outline, the lirellae 1–5 mm long and 0.15–0.25 mm wide, 0.15–0.25 mm high; stromata in section almost completely carbonized, only between lirellae with pockets of crystals and colorless hyphae; surface and margin of stromata cream-colored, disc of lirellae brown-black but with white pruina; young stromata starting out as distinctly fissurine, non-stromatoid, stellately branched lirellae. Excipulum well-developed, 10–15 µm wide, carbonized; hypothecium 50–100 µm high, carbonized; hymenium 80–100 µm high, colorless, inspersed. Epithecium granular. Paraphyses unbranched. Asci clavate, 70–90 × 10–15 µm. Ascospores 8 per ascus, oblong-oval, 3-septate, 12–17 × 5–7 µm, 2–3 times as long as wide, grey-brown, I+ vine-red. Secondary chemistry: stictic acid, cryptostictic acid.

Notes. This taxon was at first identified as an aberrant form of *Sacrographa labyrinthica*, but differs in several aspects. In the latter, the thallus is usually dark green to olive green, and the stromata are sharply delimited from the surrounding thallus even when young, differing by their minutely farinose, cream-colored to white surface. The lirellae in that species soon develop transverse splits and mature stromata are thus seemingly composed of many angular to rounded individual discs. Ascospores are slightly larger that in *S. fissurinoides*. The most striking feature of the new species are the young stromata which appear exactly as the fissurine lirellae in *Fissurina*, and only later develop into the stromata typical of *Sarcographa*. The sparsely dissected lirellae resemble those of *S. tricosa* but that species contains no lichen substances.

Sarcographa labyrinthica (Ach.) Müll. Arg. (FIG. 31G)

Specimens examined. ALAGOAS: Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (closed forest), 50 m, *Cáceres & Lücking 01-0021* (hb. Kalb, F), *01-0009* (F), *01-0025* (F), *01-0094* (F), *01-0533* (F), *01-0534* (F), *01-0545* (F), *01-0571* (F), *01-0572* (F), *01-0573* (F), *01-0025* (URM), *01-0086* (URM). Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (forest along main trail), 50 m, *Cáceres A11-100* (URM), *A29-240* (B), *A40-311* (F), *A46-410* (F), *A46-421a* (F). PERNAMBUCO: Bonito, Parque Municipal de Bonito, 8° 28' S, 35°43' W, Brejo de Altitude (high altitude rainforest), 800 m, *Cáceres & Lücking 00-0376* (B-600124188, F, URM), *00-0355* (URM), *00-0377* (URM), *00-0380* (URM). Cabo de Santo Agostinho, Reserva Ecológica de Gurjaú, 8° 19' S, 35° 04' W, Mata Atlântica (closed forest), 30 m, *Cáceres & Lücking 00-0147* (B-600124132, F), *00-0149* (B-600124133, F, URM), *00-0152* (F), *00-0148* (URM), *00-0238* (URM). Igarassu, Refúgio Ecológico Charles Darwin, 7° 50' S, 34° 54' W, Mata Atlântica (closed forest), 20 m, *Cáceres & Lücking 00-0520* (B-600124189), *00-0521* (F), *00-0519* (URM), *00-0523* (URM). Recife, Aldeia, Mata Atlântica, *R. Lücking s.n.* (URM). Recife,

Dois Irmãos, Mata Atlântica (closed forest), *Cáceres & Lücking 99-0505* (URM), *99-0506* (URM). São Lourenço da Mata, Estação Ecológica de Tapacurá, 8° 02' S, 35° 09' W, Agreste (open dry forest), 100 m, *Cáceres & Lücking 98-0265* (URM). SERGIPE: Areia Branca, Reserva Ecológica Serra de Itabaiana, 10° 45' S, 37° 20' W, Mata Atlântica (closed forest), 500 m, *Cáceres & Lücking 2201* (B), *2079* (F, URM), *2197* (URM), *2201* (URM).

Sarcographa ramificans (Kremp.) Staiger (FIG. 31H)

Specimens examined. PERNAMBUCO: Cabo de Santo Agostinho, Reserva Ecológica de Gurjaú, 8° 19' S, 35° 04' W, Mata Atlântica (closed forest), 30 m, *Cáceres & Lücking 00-0156* (B-600124190, F, URM), *00-0157* (B-600124191, hb. Kalb, F, URM).

Sarcographa tricosa (Ach.) Müll. Arg.

Specimen examined. ALAGOAS: Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (closed forest), 50 m, *Cáceres & Lücking 01-0506* (F, URM).

Sclerophyton Eschw. (Roccellaceae)

Notes. Sclerophyton resembles *Enterographa* but is distinguished by the rounded rather than acute ascospores (SPARRIUS 2004). Variation in ascomata morphology is similar, ranging from elongate lirellae to pseudostromatic, almost punctiform ascomata. *Sclerophyton elegans* is the most common species, recognized by its smooth, corticate thallus and very elongate, radiately branched ascomata. A further species, *S. extenuatum* (Nyl.) Sparrius, was reported from Bahia by SPARRIUS (2004).

Sclerophyton elegans Eschw. (FIG. 32A)

Specimen examined. ALAGOAS: Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (forest along main trail), 50 m, *M. Cáceres A21-191* (B, F, URM).

Sphinctrina Fr. (Sphinctrinaceae)

Notes. Sphinctrina has been included here although it is a genus of lichenicolous fungi rather than autonomous lichens (TIBELL 1996), but its ascomata are rather conspicuous and will be noticed by lichen collectors.

Sphinctrina tubiformis A. Massal. (FIG. 32B)

Specimens examined. ALAGOAS: Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (forest along main trail), 50 m, *M. Cáceres A18-167* (F). PERNAMBUCO: Caruaru, Instituto Pernambucano de Pesquisas Agropecuárias (IPA), 8° 17' S, 35° 58' W, Caatinga (open thornbush), 500–600 m, *Cáceres & Lücking 00-0011b* (F). Caruaru, Instituto Pernambucano de Pesquisas Agropecuárias

(IPA), 8° 17' S, 35° 58' W secondary vegetation (open area in front of main building), 500–600 m, *Cáceres & Lücking 00-0120b* (F).

Squamacidia Brako (Ramalinaceae)

Notes. *Squamacidia* was long included in *Thalloidima*, a synonym of *Toninia*, but recognized as a separate genus by BRAKO (1989, 1991; EKMAN 1996). It is most similar to *Phyllopsora* but differs in its apothecial anatomy and long, narrow ascospores, among other characters. The very robust isidia make *S. janeirensis* a very characteristic species.

Squamacidia janeirensis (Müll. Arg.) Brako (FIG. 32C)

Specimen examined. ALAGOAS: Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (closed forest), 50 m, *M. Cáceres 2023* (B, F, URM).

Stegobolus Mont. (Thelotremataceae)

Notes. The genus *Stegobolus* was reinstated to accommodate species with *Ocellularia*-type apothecial anatomy but reticulate columella (FRISCH & KALB 2006; FRISCH *et al.* 2006). Although most species of *Stegobolus* are readily identified even in the field by their conspicuous apothecia, further studies are required to clarify the delimitation of this genus with *Ocellularia* and the similar *Redingeria*. As in *Ocellularia*, *Stegobolus* also includes species with non-carbonized excipulum.

Key to species of *Stegobolus*

1a. Excipulum carbonized; ascospores brown ..... ***S. auberianus***
1b. Excipulum non-carbonized; ascospores colorless 2

2a. Ascospores transversely septate ..... ***S. anamorphus***
2b. Ascospores submuriform ..... ***S. wrightii***

Stegobolus anamorphus (Nyl.) A. Frisch & Kalb

Specimens examined. ALAGOAS: Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (closed forest), 50 m, *Cáceres & Lücking 01-0054* (F), *01-0536* (F).

Stegobolus auberianus (Mont.) A. Frisch & Kalb

Specimen examined. PERNAMBUCO: Cabo de Santo Agostinho, Reserva Ecológica de Gurjaú, 8° 19' S, 35° 04' W, Mata Atlântica (closed forest), 30 m, *Cáceres & Lücking 00-0179* (F, URM).

Stegobolus wrightii (Tuck.) A. Frisch (FIG. 32D)

Specimen examined. ALAGOAS: Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (closed forest), 50 m, *M. Cáceres 2071* (F, URM).

Stictis Pers. (Stictidaceae)

Notes. The genus *Stictis* was traditionally considered the non-lichenized counterpart of *Conotrema* (GILENSTAM 1969; SHERWOOD 1977), but molecular studies showed that lichenization can even vary within a single species, and thus the two were suggested to be united (WEDIN *et al.* 2004, 2005).

Stictis urceolata (Ach.) Gilenstam

Specimen examined. SERGIPE: Santa Luzia, Private property, 11° 19' S, 37° 27' W, Mata Atlântica (closed forest), *Cáceres & Lücking 00-0831* (F).

Stigmatochroma Marbach (Physciaceae)

Notes. *Stigmatochroma* is a further segregate of the artificial lichen genus *Buellia* s.lat., characterized by its usually yellow- or red-pruinose apothecial discs, among other characters (MARBACH 2000). The genus superficially resembles *Cresponea*, but there are fundamental anatomical and ecological differences, *Stigmatochroma* ocurring in exposed situations while *Cresponea* is a typical rainforest understory element.

Stigmatochroma gerontoides (Stirt.) Marbach (FIG. 32E)

Specimens examined. SERGIPE: Gararu, 9° 58' S, 37° 54' W, Caatinga (thornbush), 0–100 m, *M. Cáceres 2112a* (B), *2093b* (F), *2113a* (F), *2121* (F), *2109* (URM).

Strigula Fr. (Strigulaceae)

Notes. *Strigula* was for a long time restricted until restudy of corticolous pyrenocarpous lichens revealed that many are typical Strigula species (TUCKER & HARRIS 1980; HARRIS 1995). Superficially, the species are difficult to distinguish from other pyrenocarpous genera, including *Anisomeridium*, *Arthopyrenia*. *Mycomicrothelia*, *Polymeridium*, *Pseudopyrenula*, and *Pyrenula*. Anatomically, most of these genera are fundamentally different in hamathecium structure, ascus type, and ascospores, except *Anisomeridium* which differs from *Strigula* mostly by the anastomosing paraphyses and

usually broader ascospores with the proximate instead of distal cell enlarged.

Key to species of *Strigula*

1a. Ascospores muriform ..... ***S. obtecta***
1b. Ascospores transversely septate 2

2a. Perithecia subglobose (resembling Porina) ..... ***S. stigmatella***
2b. Perithecia conical..... 3

3a. Ascospores 12–17 × 4–5 µm; thallus whitish..... ***S. viridiseda***
3b. Ascospores 8–12 × 2.5–3 µm; thallus greenish..... ***S. phaea***

Strigula obtecta (Vain.) R. C. Harris (FIG. 32F)

Specimen examined. PERNAMBUCO: Bonito, Parque Municipal de Bonito, 8° 28' S, 35°43' W, Brejo de Altitude (high altitude rainforest), 800 m, *Cáceres & Lücking 00-0268* (ABL, B-600124186, F).

Strigula phaea (Ach.) R. C. Harris (FIG. 32G)

Notes. This taxon is potentially conspecific with the common foliicolous *Strigula phyllogena* (Müll. Arg.) R. C. Harris, the only difference being the *Trentepohlia* vs. *Phycopeltis* photobiont.

Specimens examined. ALAGOAS: Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (forest along main trail), 50 m, *M. Cáceres A22-193* (F), *A33-254b* (URM), *A33-260* (F). PERNAMBUCO: Cabo de Santo Agostinho, Reserva Ecológica de Gurjaú, 8° 19' S, 35° 04' W, Mata Atlântica (closed forest), 30 m, *Cáceres & Lücking 00-0182* (ABL, B-600124185, F). Igarassu, Refúgio Ecológico Charles Darwin, 7° 50' S, 34° 54' W, Mata Atlântica (closed forest), 20 m, *Cáceres & Lücking 00-0443* (B-600124215, F).

Strigula stigmatella (Ach.) R. C. Harris

Specimens examined. ALAGOAS: Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (forest along main trail), 50 m, *M. Cáceres A09-080* (F), *A28-240c* (F), *A41-319* (F), *A42-319* (F). PERNAMBUCO: Caruaru, Instituto Pernambucano de Pesquisas Agropecuárias (IPA), 8° 17' S, 35° 58' W, Caatinga (open thornbush), 500–600 m, *Cáceres & Lücking 00-0041* (B-600124216, F).

Strigula viridiseda (Nyl.) R. C. Harris (FIG. 32H)

Specimens examined. ALAGOAS: Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (closed forest), 50 m, *Cáceres & Lücking 01-0095* (F). PERNAMBUCO: Caruaru, Instituto Pernambucano de Pesquisas

Agropecuárias (IPA), 8° 17' S, 35° 58' W, Caatinga (open thornbush), 500–600 m, *Cáceres & Lücking 00-0045* (B-600124187, F), *00-0055* (B-600124217).

Syncesia Taylor (Roccellaceae)

Notes. *Syncesia* is a characteristic element of tropical forests in more exposed situations. The genus resembles *Chiodecton*, but the latter has perithecioid ascomata lacking a pruinose surface and often clavate or biclavate ascospores with up to 7 septa (TEHLER 1993). The newly described *Plectocarpon syncesioides* is very similar to *Syncesia* species but differs by its completely carbonized stromata, 5-septate ascospores, and presence of norstictic acid. Besides the two species listed below, a further species, *S. farinacea* (Fée) Tehler, was reported from Bahia (TEHLER 1993).

Key to species of *Syncesia*

1a. Thallus UV+ yellow; roccellic acid; rhizomorphs absent .....***S. effusa***
1b. Thallus UV–; schizopeltic acid; rhizomorphs present...***S. rhizomorpha***

Syncesia effusa (Fée) Tehler (FIG. 33A)

Specimen examined. ALAGOAS: Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (closed forest), 50 m, *Cáceres & Lücking 01-0002* (F, URM).

Syncesia rhizomorpha Tehler (FIG. 33B)

Specimen examined. ALAGOAS: Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (closed forest), 50 m, *M. Cáceres s.n.* (B, F). SERGIPE: Itabi, Private property, 10° 06' S, 37° 54' W, Caatinga (thornbush), 100 m, *M. Cáceres 2181* (F, URM).

Tapellaria Müll. Arg. (Ectolechiaceae)

Notes. This genus is typically foliicolous, but corticolous representatives have been reported by KALB & VĚZDA (1987). The genus is characterized by black, lecideine apothecia, strongly anastomosing paraphyses, and a campylidioid anamorph producing filiform conidia. Most similar is *Calopadia*, which differs by its biatorine apothecia and sparsely branched paraphyses (LÜCKING 2007).

Tapellaria malmei R. Sant.

Specimen examined. PERNAMBUCO: Cabo de Santo Agostinho, Reserva Ecológica de Gurjaú (Barragem), 8° 19' S, 35° 04' W, Mata Atlântica (closed forest), 30 m, Mata Atlântica, *Cáceres & Lücking 98-s.n.* (F).

Thalloloma Trevis. (Graphidaceae)

Notes. *Thalloloma* is a further segregate of the artificial genus Graphis (STAIGER 2002). It resembles *Phaeographis* in having exposed discs and thin labia with non-carbonized excipulum, but its ascospores are hyaline and I+ violet-blue. Many species have red discs containing the pigment iso-hypocrellin.

Thalloloma astroideum (Müll. Arg.) Staiger (FIG. 33C)

Specimens examined. PERNAMBUCO: Caruaru, Brejo dos Cavalos, 8° 20' S, 35° 58' W, Brejo de Altitude (high altitude rainforest), 800–900 m, *Cáceres & Lücking 00-0636* (F), *00-0640* (F). Igarassu, Refúgio Ecológico Charles Darwin, 7° 50' S, 34° 54' W, Mata Atlântica (closed forest), 20 m, *Cáceres & Lücking 00-0492* (B, F, URM). SERGIPE: Santa Luzia, Private property, 11° 19' S, 37° 27' W, Mata Atlântica (closed forest), *Cáceres & Lücking 00-0875* (B).

Thelenella Nyl. (Thelenellaceae)

Notes. *Thelenella* was monographed by MAYRHOFER (1987). The genus resembles certain other pyrenocarpous genera, such as *Phyllobathelium* and some species in the Monoblastiaceae due to its perithecia covered with a thalline layer, but its photobiont is chlorococcoid, and their are anatomical differences in hamathecium and ascus structure (MAYRHOFER 1987; HARRIS 1995). The related *Aspidothelium* lacks thalline tissue on the perithecial wall, often produces perithecial appendages, and has a different ascospore type (LÜCKING 1998).

Thelenella paraguayensis Malme

Specimen examined. ALAGOAS: Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (forest along main trail), 50 m, *M. Cáceres A09-079* (F), *A24-197* (F).

Thelotrema Ach. (Thelotremataceae)

Notes. *Thelotrema* traditionally included species with hyaline, muriform ascospores and, with the concept of HALE (1980), species with non-carbonized excipulum producing periphysoids (although Hale also included species lacking periphysoids in that genus). With the recent revision of FRISCH (2006), the genus is now restricted to species with non-carbonized excipulum producing periphysoids and an incurved to erect double margin, among other characters. The chroodiscoid species were separated in the genus *Chapsa*, while the species with urceolate apothecia lacking periphysoids are now placed in *Topeliopsis* (KANTVILAS & VĚZDA 2000; KALB 2001; FRISCH

& KALB 2006). A few species with myriotremoid apothecia producing peri-physoids (*Thelotrema glaucopallens* group; FRISCH 2006) are still retained in *Thelotrema* but probably do not belong here. Besides the latter, no genuine *Thelotrema* was found in the present material, which is consistent with the genus being mostly found in tropical montane regions. However, four sterile, sorediate taxa were found which are here listed as *Thelotrema* species but their generic assignment must await more detailed chemical and molecular studies.

Thelotrema glaucopallens Nyl.

Specimens examined. ALAGOAS: Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (forest along main trail), 50 m, *M. Cáceres A17-153* (B), *A17-154* (URM), *A25-214* (B, F, URM).

Thelotrema spec. A

Specimens examined. ALAGOAS: Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (forest along main trail), 50 m, *M. Cáceres A05-039* (F), *A14-132* (F), *A23-199* (F), *A40-301* (F), *A40-310* (F), *A46-424* (F), *A47-443* (F). PERNAMBUCO: Igarassu, Refúgio Ecológico Charles Darwin, 7° 50' S, 34° 54' W, Mata Atlântica (closed forest), 20 m, *Cáceres & Lücking 00-0395* (F).

Thelotrema spec. B

Specimen examined. PERNAMBUCO: Igarassu, Refúgio Ecológico Charles Darwin, 7° 50' S, 34° 54' W, Mata Atlântica (closed forest), 20 m, *Cáceres & Lücking 00-0481* (F).

Thelotrema spec. C

Specimen examined. ALAGOAS: Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (closed forest), 50 m, *Cáceres & Lücking 01-0125* (F).

Thelotrema spec. D

Specimens examined. ALAGOAS: Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (closed forest), 50 m, *M. Cáceres 2017* (F, URM). Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (forest along main trail), 50 m, *M. Cáceres A06-048* (F).

Traponora Aptroot (Lecanoraceae)

Notes. The genus *Traponora* was established for a new species in the Lecanoraceae with small apothecia and stellate thalline margin (APTROOT *et*

al. 1997). The genus seems to be widespread in the tropics but is under-collected due to its small, inconspicuous thalli and apothecia.

Traponora spec.

Specimen examined. PERNAMBUCO: Caruaru, Brejo dos Cavalos, 8° 20' S, 35° 58' W, Brejo de Altitude (high altitude rainforest), 800–900 m, *Cáceres & Lücking 00-0584* (F).

Tricharia Fée (Gomphillaceae)

Notes. *Tricharia* is a chiefly foliicolous genus characterized by black sterile thallus setae and sessile, biatorine apothecia with proso- to paraplectenchymatous excipulum (LÜCKING *et al*. 2005). A few species are corticolous or found both on leaves and bark.

Tricharia vainioi R. Sant.

Specimen examined. PERNAMBUCO: Caruaru, Brejo dos Cavalos, 8° 20' S, 35° 58' W, Brejo de Altitude (high altitude rainforest), 800–900 m, *Cáceres & Lücking 00-0599b* (B-600124028).

Trichothelium Müll. Arg. (Porinaceae)

Notes. *Trichothelium* is another, chiefly foliicolous genus (LÜCKING 1998). Its separation from *Porina*, especially the *P. nitidula* group, is not clear (HAFELLNER & KALB 1995; HARRIS 1995; BALOCH & GRUBE 2006), but presently, the genus is restricted to species with mostly black, setose perithecia in which the setae are formed by conglutinate hyphae (LÜCKING 1998, 2004; 2007). Several species seem to be exclusively corticolous (LÜCKING & CÁCERES 2004).

Key to species of *Trichothelium*

1a. Ascospores submuriform, 5–10 µm broad ..... ***T. angustisporum***
1b. Ascospores muriform, 10–20 µm broad..... ***T. horridulum***

Trichothelium angustisporum Cáceres & Lücking

Specimen examined. PERNAMBUCO: Caruaru, Brejo dos Cavalos, 8° 20' S, 35° 58' W, Brejo de Altitude (high altitude rainforest), 800–900 m, *Cáceres & Lücking 00-0597* (B, F, URM).

Trichothelium horridulum (Müll. Arg.) R. Sant. (FIG. 33D)

Specimens examined. PERNAMBUCO: Bonito, Parque Municipal de Bonito, 8° 28' S, 35°43' W, Brejo de Altitude (high altitude rainforest), 800 m, *Cáceres & Lücking 00-0278* (B-

600124090, URM), *00-0280* (B-600124198, F), *00-0307* (B-600124213), *00-0277a* (F), *00-0279* (F), *00-0306* (URM). Caruaru, Brejo dos Cavalos, 8° 20' S, 35° 58' W, Brejo de Altitude (high altitude rainforest), 800–900 m, *Cáceres & Lücking 00-0596* (F).

Trypethelium Spreng. (Trypetheliaceae)

Notes. Besides *Pyrenula*, *Trypethelium* is the most conspicuous, speciose, abundant, and widespread genus of tropical pyrenocarpous lichens (HARRIS 1986). The genus is in urgent need of revision; presently, it includes all species with solitary to aggregate perithecia with separate ostioles and transversely septate ascospores, except those placed in *Bathelium* (HARRIS 1995). The family was recently shown to belong in Dothideomycetes, unrelated to the Pyrenulaceae in the Eurotiomycetes (DEL PRADO *et al*. 2006).

Key to species of *Trypethelium*

1a. Yellow-orange pigment, K+ purple present; ascospores 3–15-septate 2
1b. No pigment present; ascospores 3-septate only..... 4

2a. Thallus color orange, K+ purple; ascospores 3-septate, 20–28 × 7–9 µm..... ***T. aeneum***
2b. Thallus color brown, K–; ascospores 9–15-septate, larger..... 3

3a. Ascospores 9–13-septate, 40–50 × 9–12 µm; yellow crystals in pseudostromata ..... ***T. eluteriae***
3b. Ascospores 11–15-septate, 60–80 × 10–12 µm; orange crystals in pseudostromata ..... ***T. subeluteriae***

4a. Ascomata black, exposed ..... ***T. tropicum***
4b. Ascomata covered by thallus tissue..... 5

5a. Thallus pale yellow, UV+ yellow..... ***T. nitidiusculum***
5b. Thallus green, UV– ..... ***T. ochroleucum***

Trypethelium aeneum (Eschw.) Zahlbr.

Specimen examined. ALAGOAS: Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (closed forest), 50 m, *Cáceres & Lücking 01-0517a* (F).

Trypethelium eluteriae Spreng. (FIG. 33E)

Specimens examined. ALAGOAS: Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (closed forest), 50 m, *Cáceres & Lücking 01-0085* (B-600124140). Pernambuco: São Lourenço da Mata, Estação Ecológica

de Tapacurá, 8° 02' S, 35° 09' W, Agreste (open dry forest), 100 m, *Cáceres & Lücking 98-0510* (F), *98-0266* (URM), *98-0510* (URM). SERGIPE: Ribeira, Mata Atlântica, *Cáceres 2058* (F).Sergipe: Ribeira, Mata Atlântica, *M. Cáceres 2058* (URM).

Trypethelium nitidiusculum (Nyl.) R. C. Harris

Specimens examined. ALAGOAS: Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (closed forest), 50 m, *Cáceres & Lücking 01-0507* (F), *01-0509* (F), *01-0512* (F), *01-0601* (URM). PERNAMBUCO: Cabo de Santo Agostinho, Reserva Ecológica de Gurjaú, 8° 19' S, 35° 04' W, Mata Atlântica (closed forest), 30 m, *Cáceres & Lücking 00-0178* (B-600124199, F). Caruaru, Brejo dos Cavalos, 8° 20' S, 35° 58' W, Brejo de Altitude (high altitude rainforest), 800–900 m, *Cáceres & Lücking 00-0632* (F, URM). Igarassu, Refúgio Ecológico Charles Darwin, 7° 50' S, 34° 54' W, Mata Atlântica (closed forest), 20 m, *Cáceres & Lücking 00-0441* (B-600124192), *00-0439* (B-600124200), *00-0436* (F), *00-0437* (F), *00-0438* (F), *00-0440* (URM). RIO GRANDE DO NORTE: Baía Formosa, Reserva Particular do Patrimônio Natural (RPPN) Mata Estrela Senador Antônio Farias, 06° 22' S, 35° 01' W, Mata Atlântica (closed forest), 0 m, *M. Cáceres 01-0178* (F, URM).

Trypethelium ochroleucum (Eschw.) Nyl. (FIG. 33F)

Specimens examined. ALAGOAS: Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (closed forest), 50 m, *Cáceres & Lücking 01-0023* (B), *01-0508* (F), *01-0517b* (F), *01-0023* (URM). PERNAMBUCO: Bonito, Parque Municipal de Bonito, 8° 28' S, 35°43' W, Brejo de Altitude (high altitude rainforest), 800 m, *Cáceres & Lücking 00-0289* (B-600124194), *00-0270* (F), *00-0315* (F), *00-0289* (URM). Cabo de Santo Agostinho, Reserva Ecológica de Gurjaú, 8° 19' S, 35° 04' W, secondary vegetation (open area), 30 m, *Cáceres & Lücking 00-0259* (B-600124193, URM). Caruaru, Brejo dos Cavalos, 8° 20' S, 35° 58' W, Brejo de Altitude (high altitude rainforest), 800–900 m, *Cáceres & Lücking 00-0555* (F). Caruaru, Instituto Pernambucano de Pesquisas Agropecuárias (IPA), 8° 17' S, 35° 58' W, Caatinga (open thornbush), 500–600 m, *Cáceres & Lücking 00-0032* (F). São Lourenço da Mata, Estação Ecológica de Tapacurá, 8° 02' S, 35° 09' W, Agreste (open dry forest), 100 m, *Cáceres & Lücking 99-0600* (F, URM). SERGIPE: Itabi, Private property, 10° 06' S, 37° 54' W, Caatinga (thornbush), 100 m, *Cáceres 2180* (F, URM). Santa Luzia, Private property, 11° 19' S, 37° 27' W, Mata Atlântica (closed forest), *Cáceres & Lücking 00-0896* (B-600124226), *00-0846* (F), *00-0878* (F), *00-0895a* (F). Ribeira, Mata Atlântica, *M. Cáceres 2053* (B, F, URM), *2028* (F, URM).

Trypethelium subeluteriae Makhija & Patw.

Specimens examined. ALAGOAS: Barra de São Miguel, Reserva Particular do Patrimônio Natural (RPPN) Rosa do Sol, 09° 51' S, 35° 53' W, Mata Atlântica (closed forest), 50 m, *M. Cáceres 01-0144* (B, URM), *01-0134* (URM). Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (closed forest), 50 m, *M. Cáceres 2019* (B, duplicate, F, URM), *01-0010* (B-600124138), *01-0020* (F), *01-0021* (F), *01-0014* (URM), *01-0024* (URM). PERNAMBUCO: Cabo de Santo Agostinho, Reserva Ecológica de Gurjaú, 8° 19' S, 35° 04' W, secondary vegetation (open area), 30 m, *Cáceres & Lücking 00-0234* (F), *00-0233* (URM). Caruaru, Brejo dos Cavalos, 8° 20' S, 35° 58' W, Brejo de Altitude (high altitude rainforest), 800–900 m, *Cáceres & Lücking 00-0631* (F). Caruaru, Instituto Pernambucano de Pesquisas Agropecuárias (IPA), 8° 17' S, 35°

58' W, Caatinga (open thornbush), 500–600 m, *Cáceres & Lücking 00-0038* (B-600124201). Caruaru, Instituto Pernambucano de Pesquisas Agropecuárias (IPA), 8° 17' S, 35° 58' W, secondary vegetation (open area in front of main building), 500–600 m, *Cáceres & Lücking 00-0133* (B-600124202, F, URM), *00-0134* (B-600124203, F), *00-0038* (F), *00-0042* (F), *00-0037* (URM), *00-0043* (URM), *00-0135* (URM), *00-0136* (URM). Igarassu, Refúgio Ecológico Charles Darwin, 7° 50' S, 34° 54' W, Mata Atlântica (closed forest), 20 m, *Cáceres & Lücking 00-0435* (B-600124204). Recife, Universidade Federal de Pernambuco (UFPE), secondary vegetation on campus, *Cáceres & Lücking 98-s.n.* (URM). SERGIPE: Areia Branca, Reserva Ecológica Serra de Itabaiana, 10° 45' S, 37° 20' W, Mata Atlântica (closed forest), 500 m, *M. Cáceres 2075* (B, URM), *2079* (URM). Gararu, 9° 58' S, 37° 54' W, Caatinga (thornbush), 0–100 m, *M. Cáceres 2137* (F), *2139* (URM). Itabi, Private property, 10° 06' S, 37° 54' W, Caatinga (thornbush), 100 m, *M. Cáceres 2166* (B, F), *2192* (URM).

Trypethelium tropicum (Ach.) Müll. Arg. (FIG. 33G)

Specimens examined. PERNAMBUCO: Bonito, Parque Municipal de Bonito, 8° 28' S, 35°43' W, Brejo de Altitude (high altitude rainforest), 800 m, *Cáceres & Lücking 00-264* (B, F, URM). Caruaru, Brejo dos Cavalos, 8° 20' S, 35° 58' W, Brejo de Altitude (high altitude rainforest), 800–900 m, *Cáceres & Lücking 00-0554* (B-600124206, URM), *00-0662* (B-600124207). Igarassu, Refúgio Ecológico Charles Darwin, 7° 50' S, 34° 54' W, Mata Atlântica (closed forest), 20 m, *Cáceres & Lücking 00-0442* (B-600124205, F), *00-0457* (F). São Lourenço da Mata, Estação Ecológica de Tapacurá, 8° 02' S, 35° 09' W, Agreste (open dry forest), 100 m, *Cáceres & Lücking 98-0262* (F). SERGIPE: Gararu, 9° 58' S, 37° 54' W, Caatinga (thornbush), 0–100 m, *M. Cáceres 2134* (F). Itabi, Private property, 10° 06' S, 37° 54' W, Caatinga (thornbush), 100 m, *M. Cáceres 2184* (B, F), *2189* (B), *2173* (F, URM), *2189* (URM).

Tylophoron Nyl. ex Stizenb. (incertae sedis)

Notes. *Tylophoron* is a widespread and common tropical element, usually forming large colonies on trunks of old, exposed trees. The cigarette-shaped mazaedia and mold-like, grey-brown anamorph are very characteristic. The systematic position of the genus is unknown (TIBELL 1996).

Tylophoron moderatum Nyl.

Specimens examined. ALAGOAS: Pilar, Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Pedro, 09° 37' S, 35° 58' W, Mata Atlântica (forest along main trail), 50 m, *M. Cáceres A07-055* (F), *A07-056* (F).

Vainionora Kalb (Lecanoraceae)

Notes. *Vainionora* was segregated from *Lecanora* on account of the dark hypothecium and shorter conidia (KALB 1991, 2004; KALB & ELIX 2004). However, several species of *Lecanora* have a dark hypothecium (LUMBSCH *et al.* 1996; UPRETI & CHATTERJEE 1997), and the taxon listed below looks indeed very similar to species of *Lecanora* with dark hypothecium, so the separation between these two groups remains unclear.

Vainionora flavovirens (Fée) Kalb (FIG. 33H)

Specimens examined. PERNAMBUCO: Caruaru, Brejo dos Cavalos, 8° 20' S, 35° 58' W, Brejo de Altitude (high altitude rainforest), 800–900 m, *Cáceres & Lücking 00-0659* (F).

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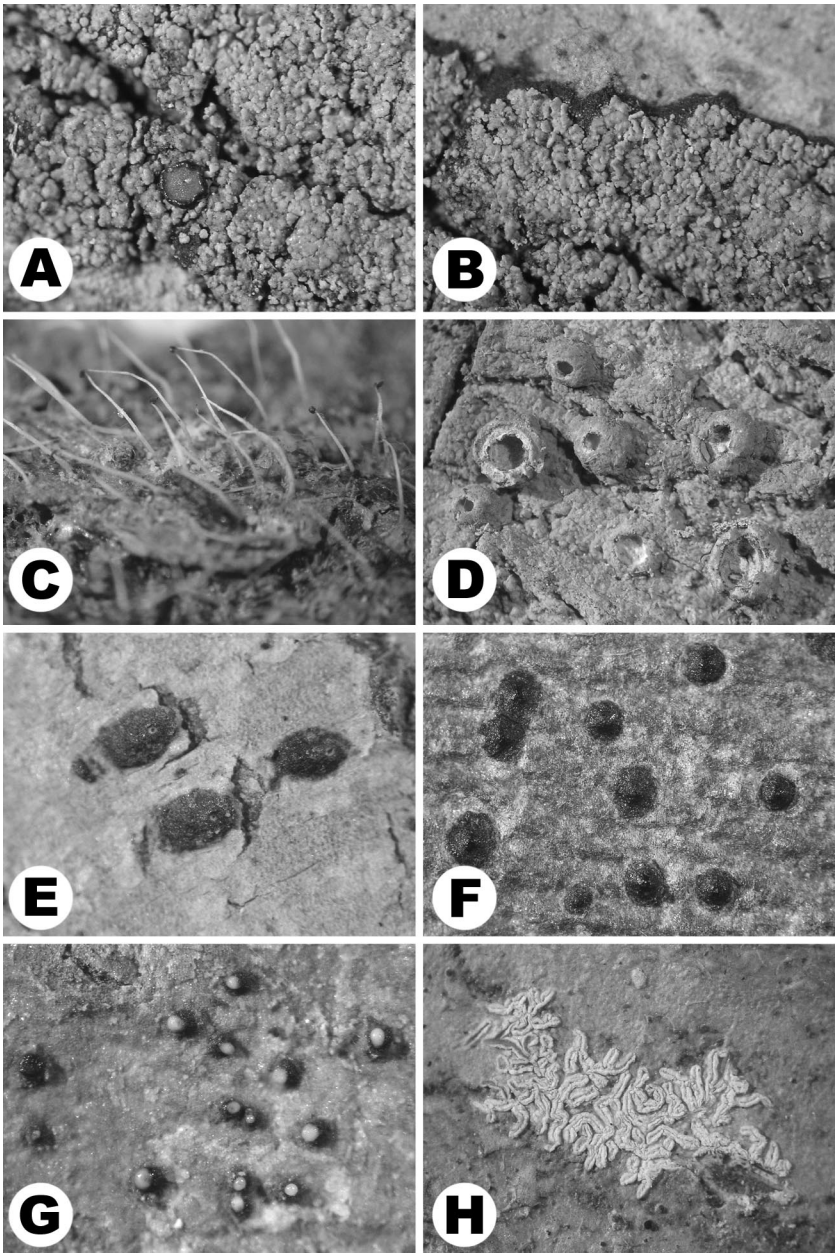


Figure 2: A–B. *Aciculopsora cinerea* [00-310a]; C. *Aderkomyces heterellus* [00-142]; D. *Ampliotrema amplius* [00-269]; E. *Anisomeridium americanum* [00-820]; F. *Anisomeridium tamarindii* [00-40]; G. *Anisomeridium* spec. [A32-249]; H. *Anomomorpha aggregans* [00-527]

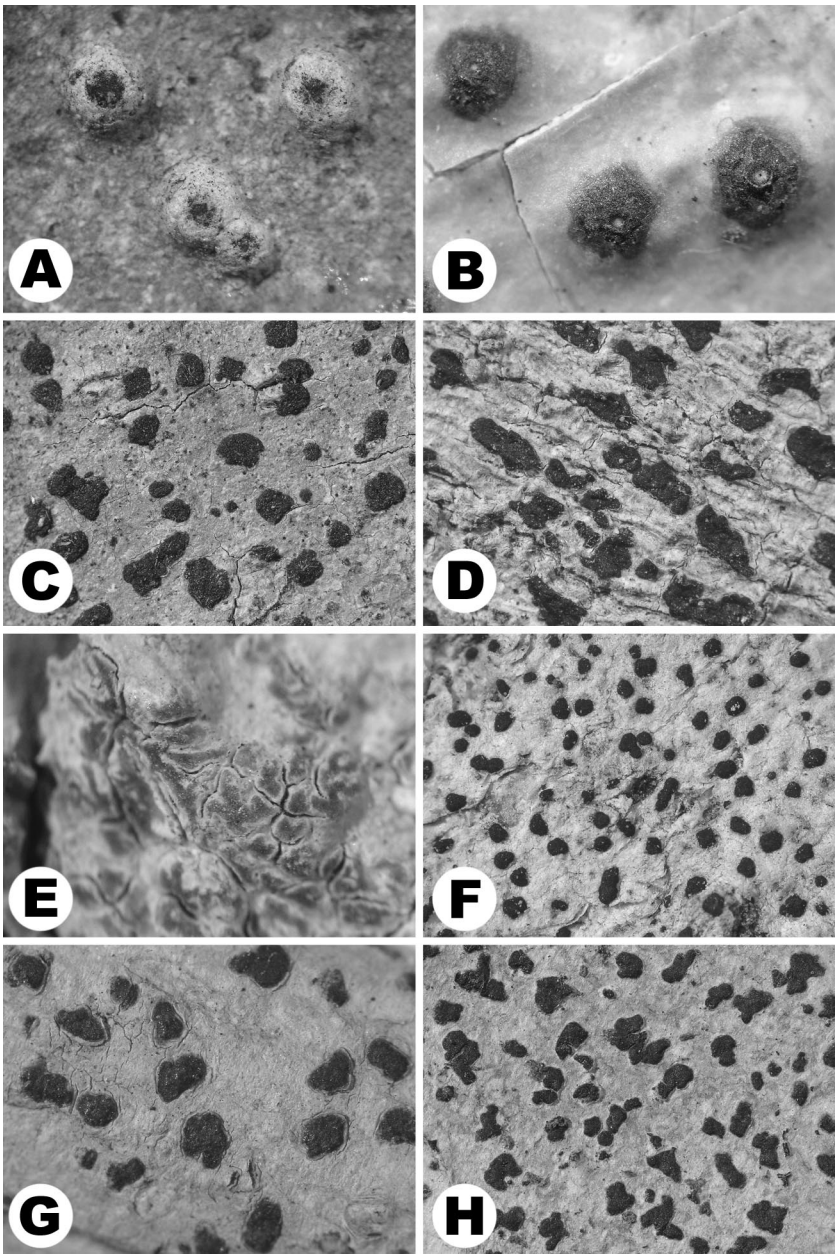


Figure 3: A. *Anthracothecium duplicans* [00-29]; B. *A. prasinum* [01-187]; C. *Arthonia bessalis* [01-132]; D. *A. complanata* [01-155]; E. *A. aff.* polygramma [00-225]; F. *A. aff. interveniens* [A45-364]; G. *A. aff. microsperma* [s.n.]; H. *A. platygraphidea* [00-236].

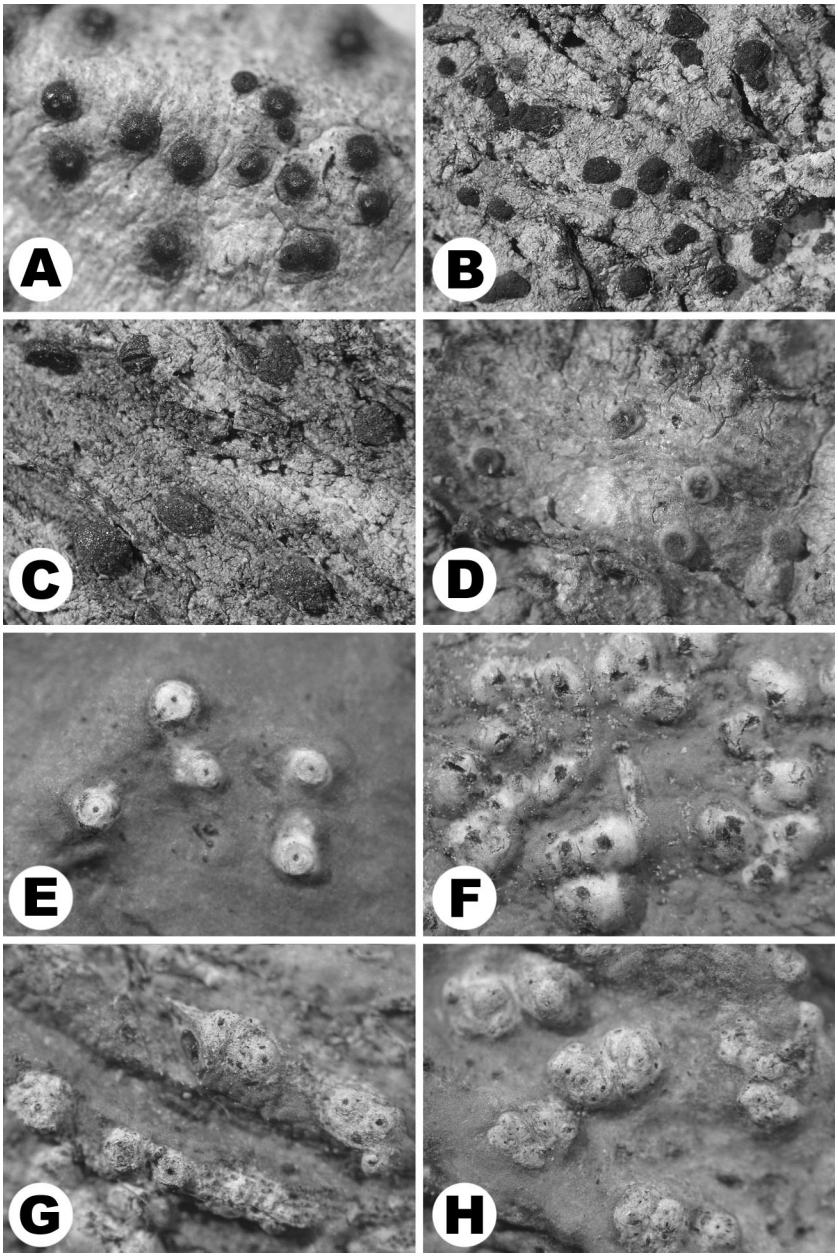


Figure 4: A. *Arthopyrenia cinchonae* [2106]; B. *Arthothelium* spec. [00-822]; C. *A. aff. spectabile* [00-188]; D. *Aspidothelium geminiparum* [00-676c]; E. *Astrothelium eustomum* [2076]; F. *A. aff. leucothelium* [00-313]; G. *A. scorioides* [00-296]; H. *A. variolosum* [A43-341].

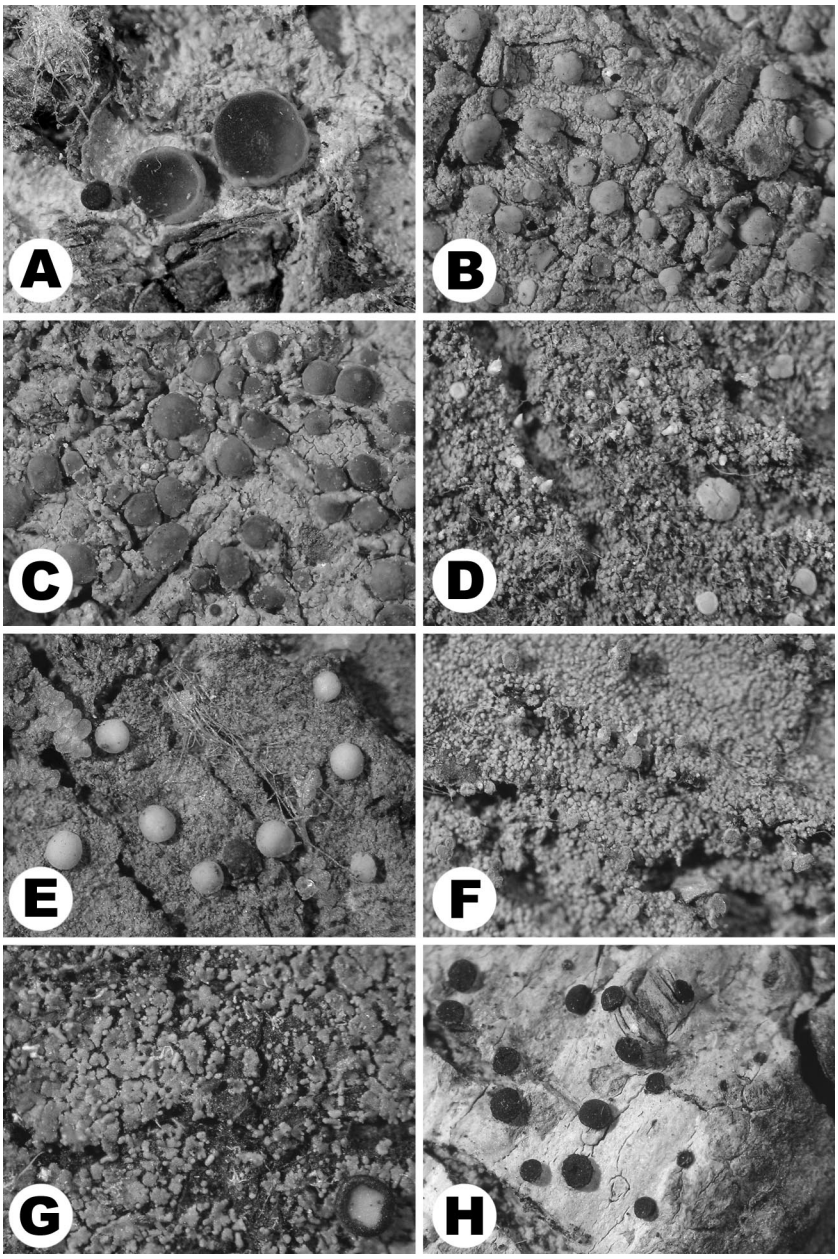


Figure 5: A. *Bacidia fluminensis* [00-573]; B. *B. medialis* [00-76]; C. *B. russeola* [00-106]; D. *Bacidina digitalis* [A29-243]; E. *B. multiseptata* [00-459b]; F. *B. penicillata* [00-538]; G. *Bacidiopsora oryzabana* [2042]; H. *Bactrospora myriadea* [s.n.]

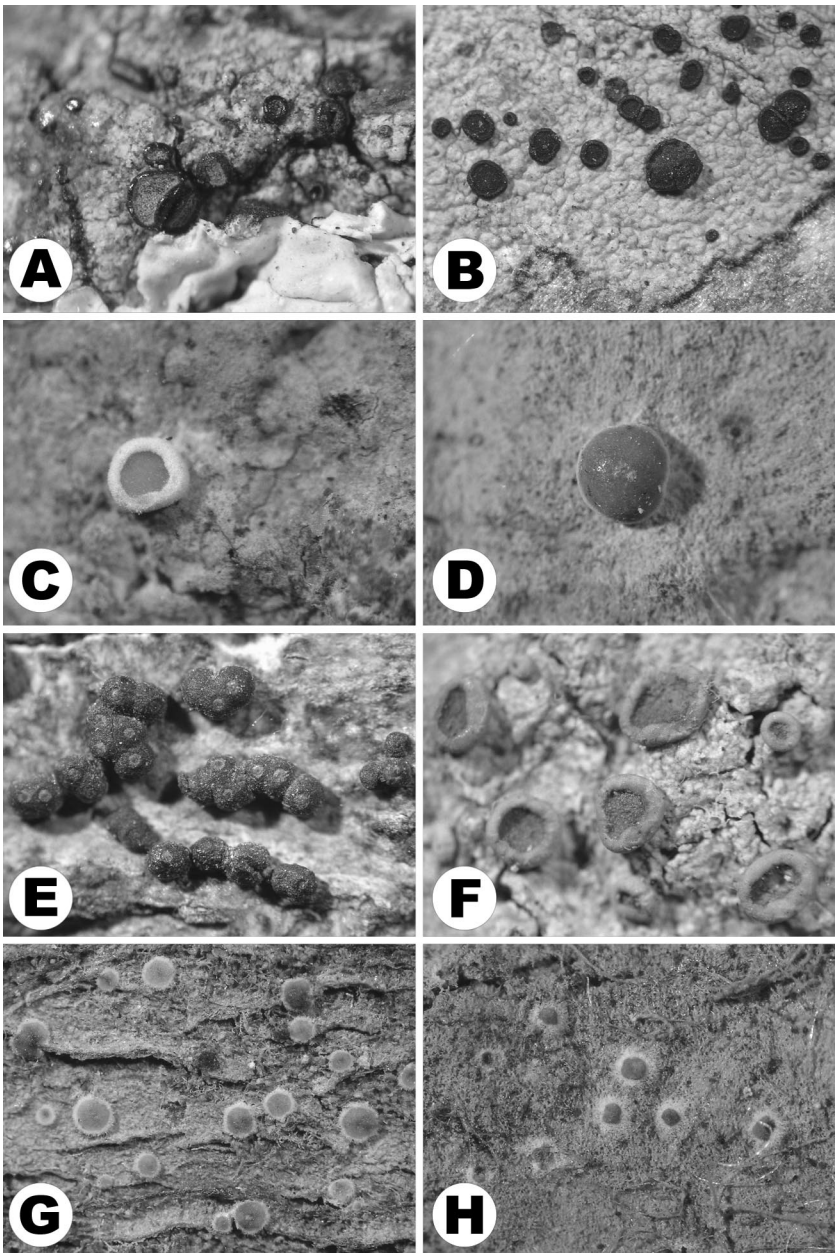


Figure 6: A. *Baculifera endochlora* [98-500b]; B. *B. pseudomicromera* [00-73]; C. *Bapalmuia halleana* [01-530]; D. *B. lafayetteana* [A16-142]; E. *Bathelium madreporiforme* [98-258]; F. *Brigantiaea leucoxantha* [00-574]; G. *Byssoloma leucoblepharum* [00-660]; H. *B. vanderystii* [A16-141].

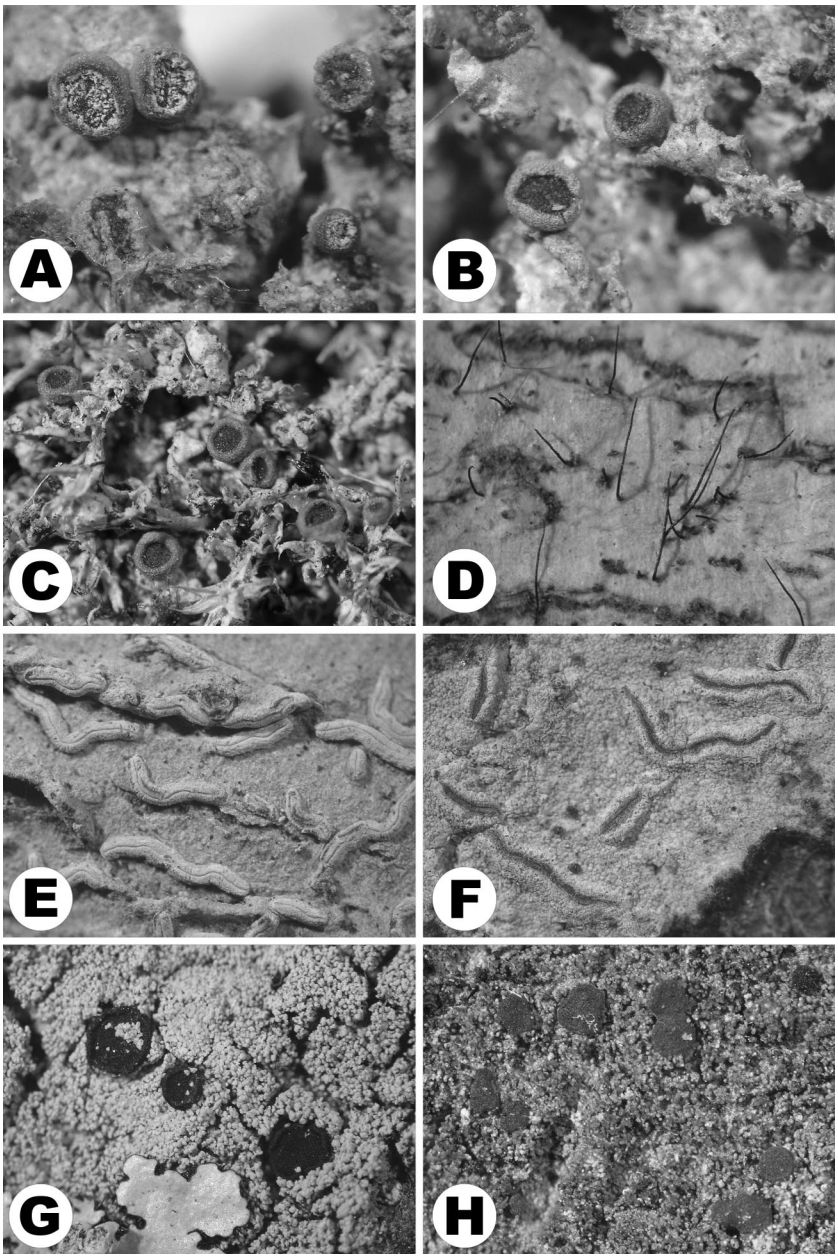


Figure 7: A-B. *Calopadia bonitensis* [00-337]; C. *C. subcoerulescens* [00-340]; D. *Caprettia amazonensis* [00-221]; E. *Carbacanthographis marcescens* [01-168]; F. *C. stictica* [00-840]; G. *Catillochroma endochroma* [01-535]; H. *C. anaglyptica* [01-555].

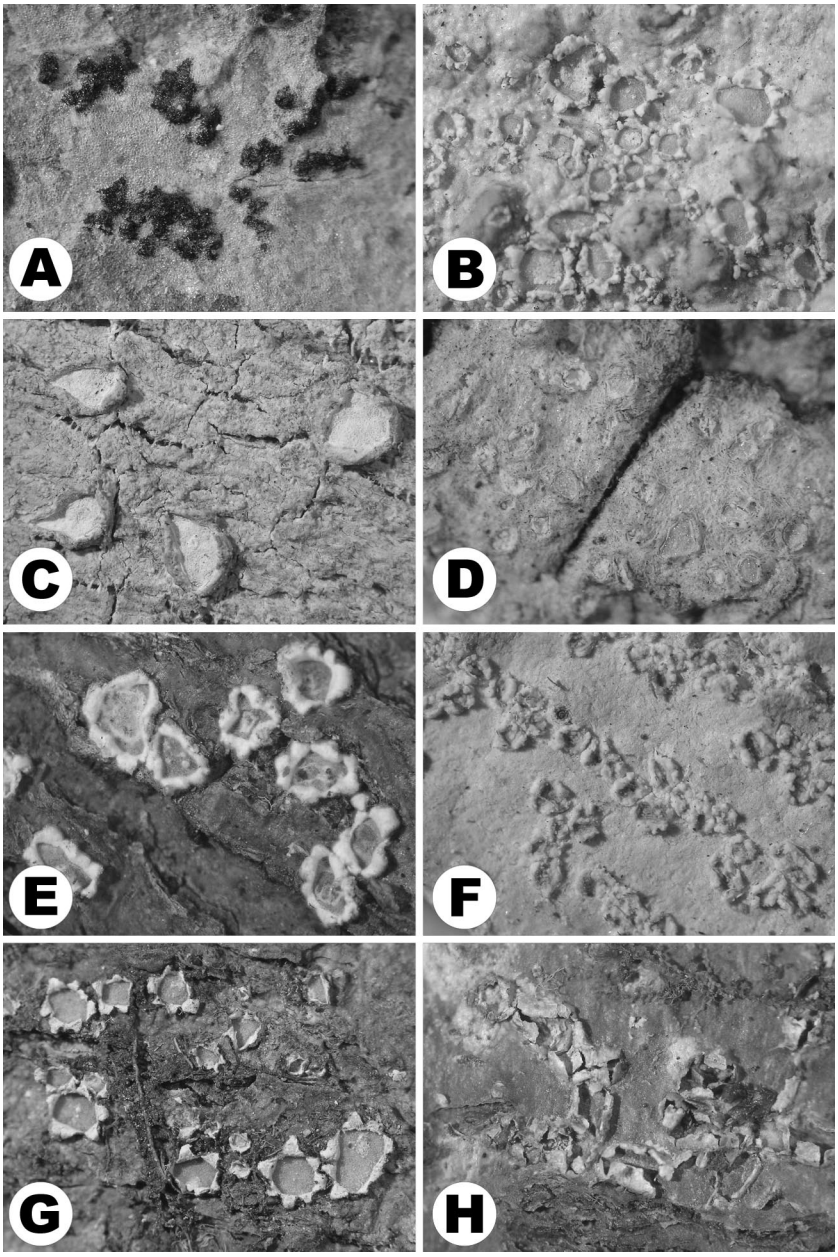


Figure 8: A. *Celothelium aciculiferum* [00-394]; B. *Chapsa alborosella* [A8-66]; C. *C. dilatata* [00-617]; D. *C. indica* [01-142]; E. *C. leprieurii* [00-431]; F. *C. patens* [00-529a]; G. *C. platycarpella* [00-328]; H. *C. sublilacina* [00-288].

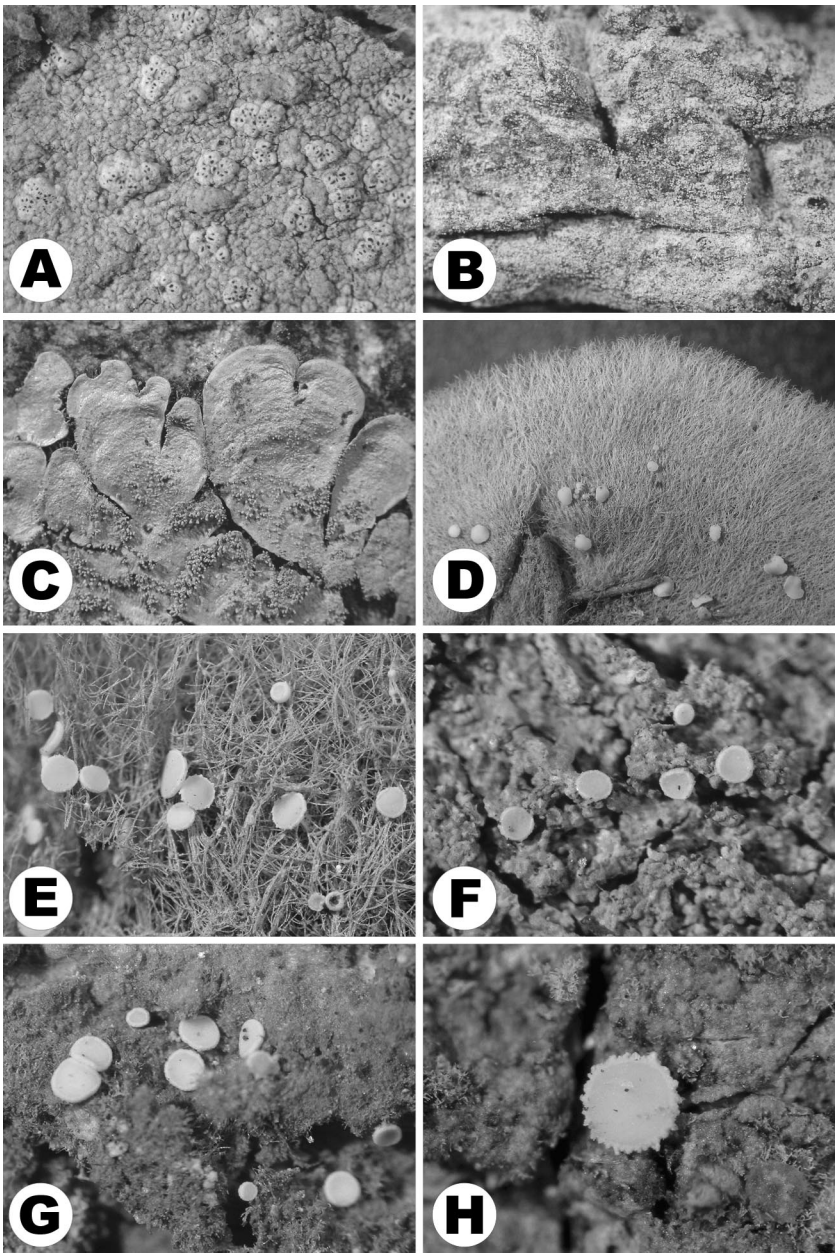


Figure 9: A. *Chiodecton malmei* [A3-24]; B. *Chrysothrix chlorina* [01-137]; C. *Coccocarpia palmicola* [00-143]; D. *Coenogonium confervoides* [2002]; E. *C. disjunctum* [00-670]; F. *C. isidiosum* [2047]; G. *C. moniliforme* [2185]; H. *C. subdentatum* [01-152]

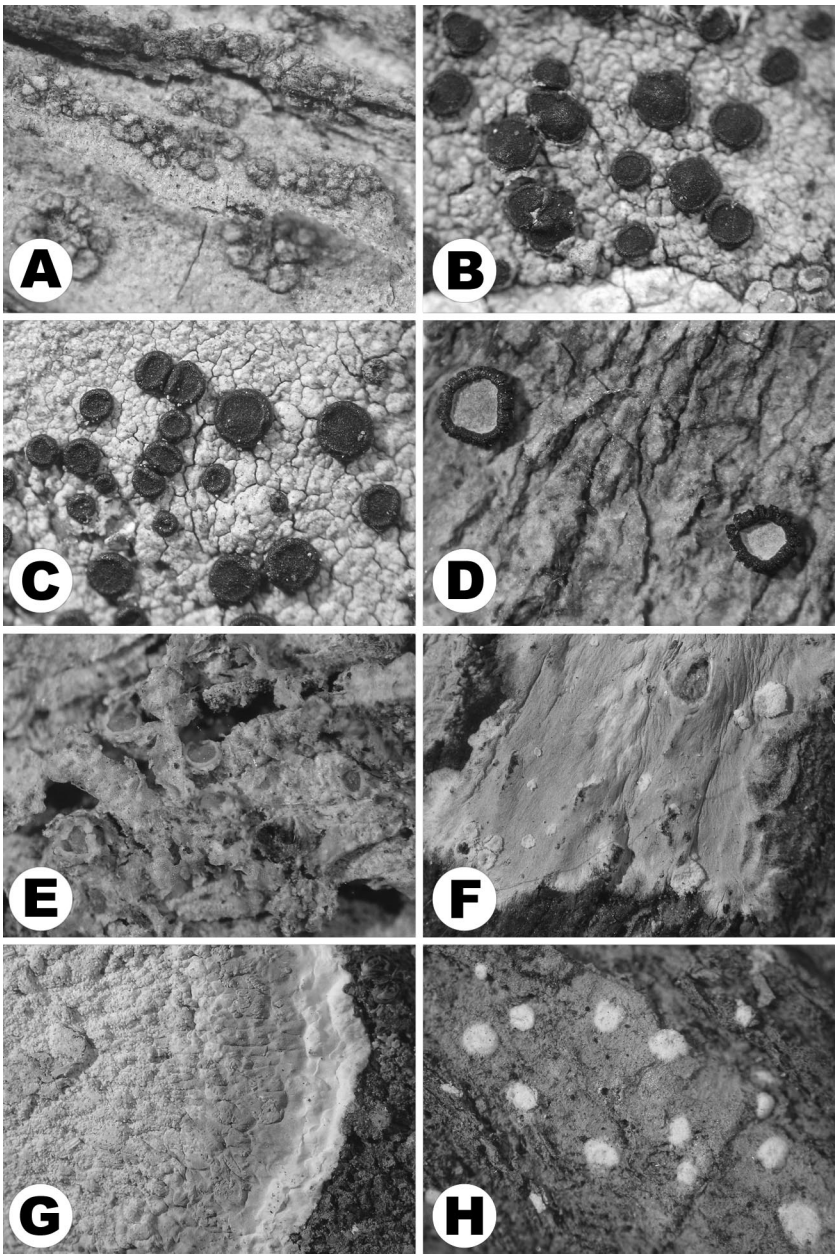


Figure 10: A. *Coniocarpum cinnabarinum* [00-24]; B. *Cratiria lauricassiae* [00-84a]; C. *C. obscurior* [00-75]; D. *Cresponea melanocheloides* [01-189a]; E. *Cryptolechia nana* [A33-259]; F. *Cryptothecia punctosorediata* [2072]; G. *C. striata* [01-504]; H. *C. subcandida* [00-693].

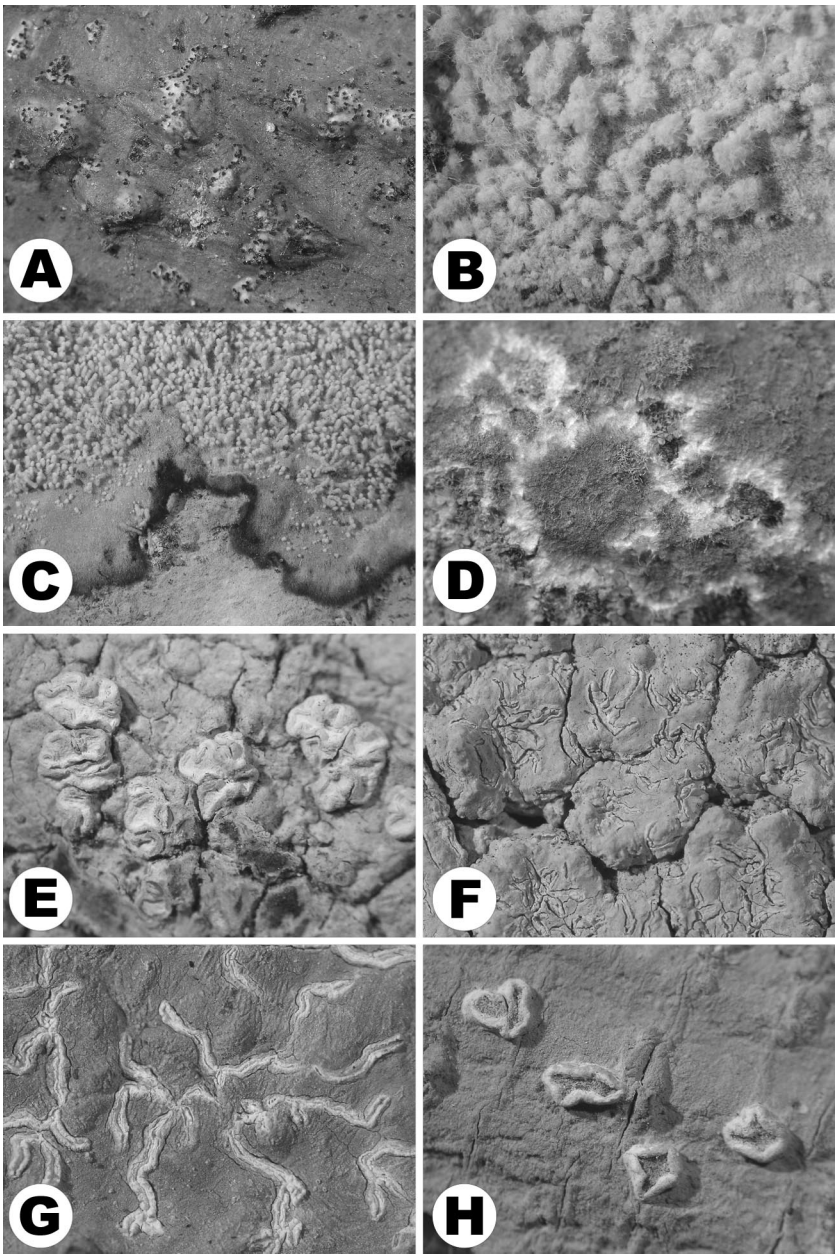


Figure 11: A. *Cryptothelium sepultum* [2080]; B. *Dichosporidium lanuginosum* [00-280]; C. *D. nigrocinctum* [A12-114a]; D. *Dictyonema phyllogenum f. nitidum* [00-600]; E. *Diorygma alagoense* [01-16]; F. D. *hieroglyphicum* [2157]; G. *D. poitaei* [A5-36]; H. *D. reniforme* [00-388].

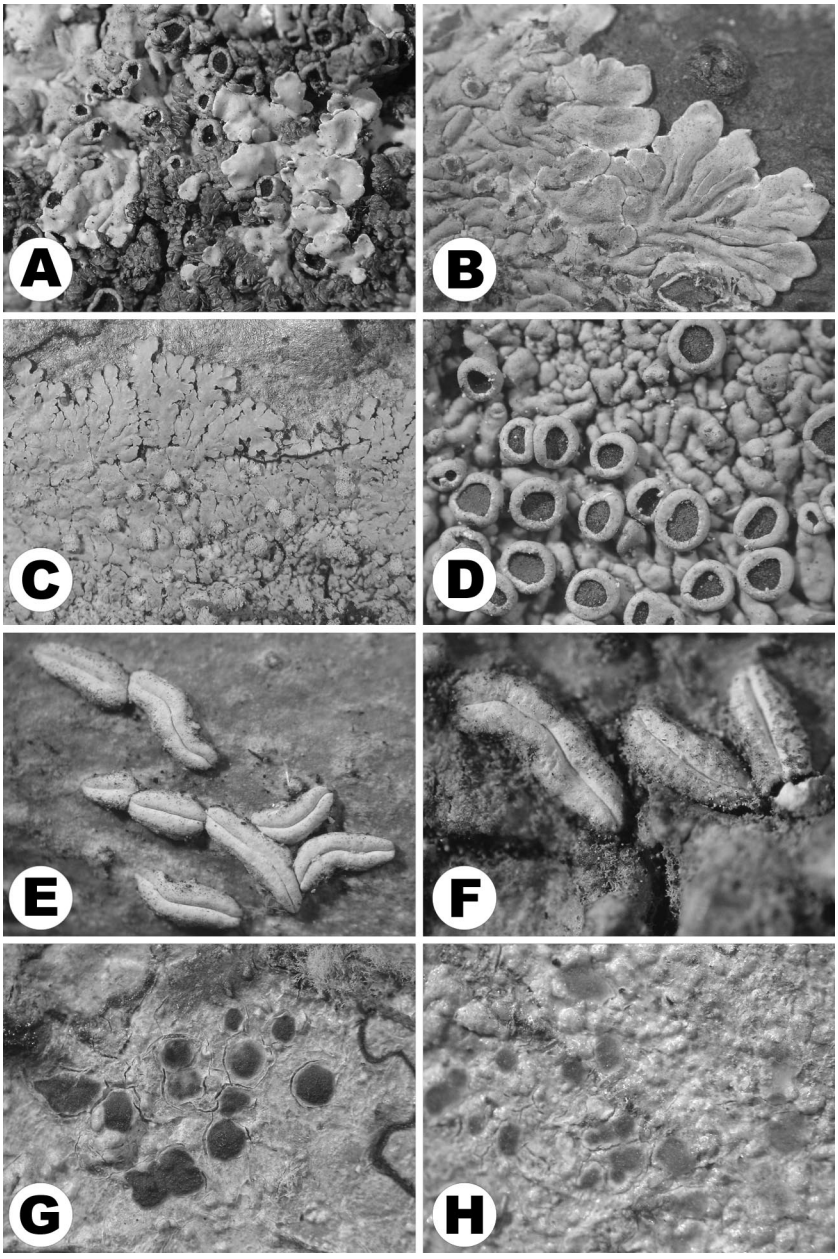


Figure 12: A. *Dirinaria confluens* [98-500a]; B. *D. leopoldii* [00-20b]; C. *D. picta* [A4-29]; D. *D. purpurascens* [00-110]; E. *Dyplolabia afzelii* [00-245]; F. *D. oryzoides* [01-22a]; G. *Echinoplaca bispora* [00-604]; H. *E. caruaruensis* [00-606].

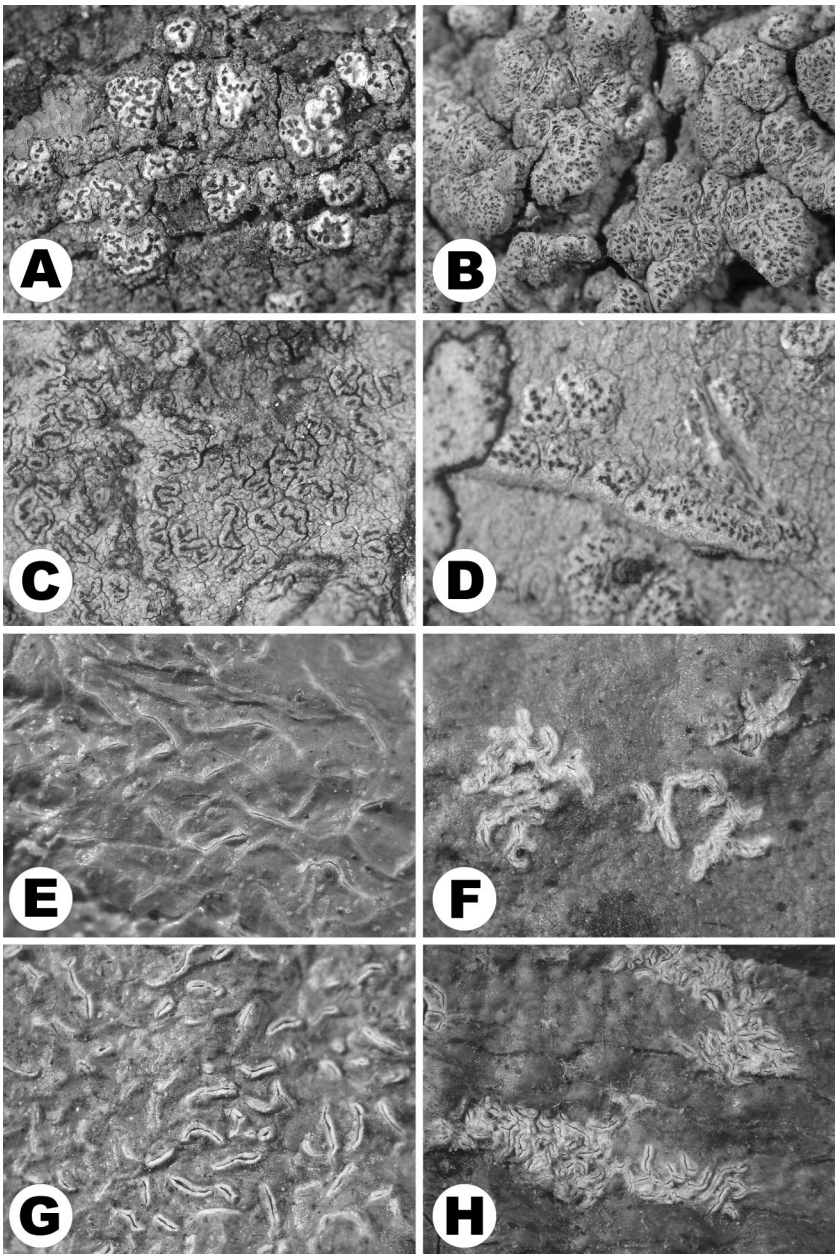


Figure 13: A. *Enterographa chiodectonoides* [2002]; B. *E. cumpunctula* [01-11]; C. *E. sipmanii* [00-34b]; D. *E. subquassiaecola* [00-31]; E. *Fissurina dumastii* [01-544]; F. *F. incrustans* [A16-140]; G. *F. instabilis* [A43-335]; H. *F. radiata* [A46-417a].

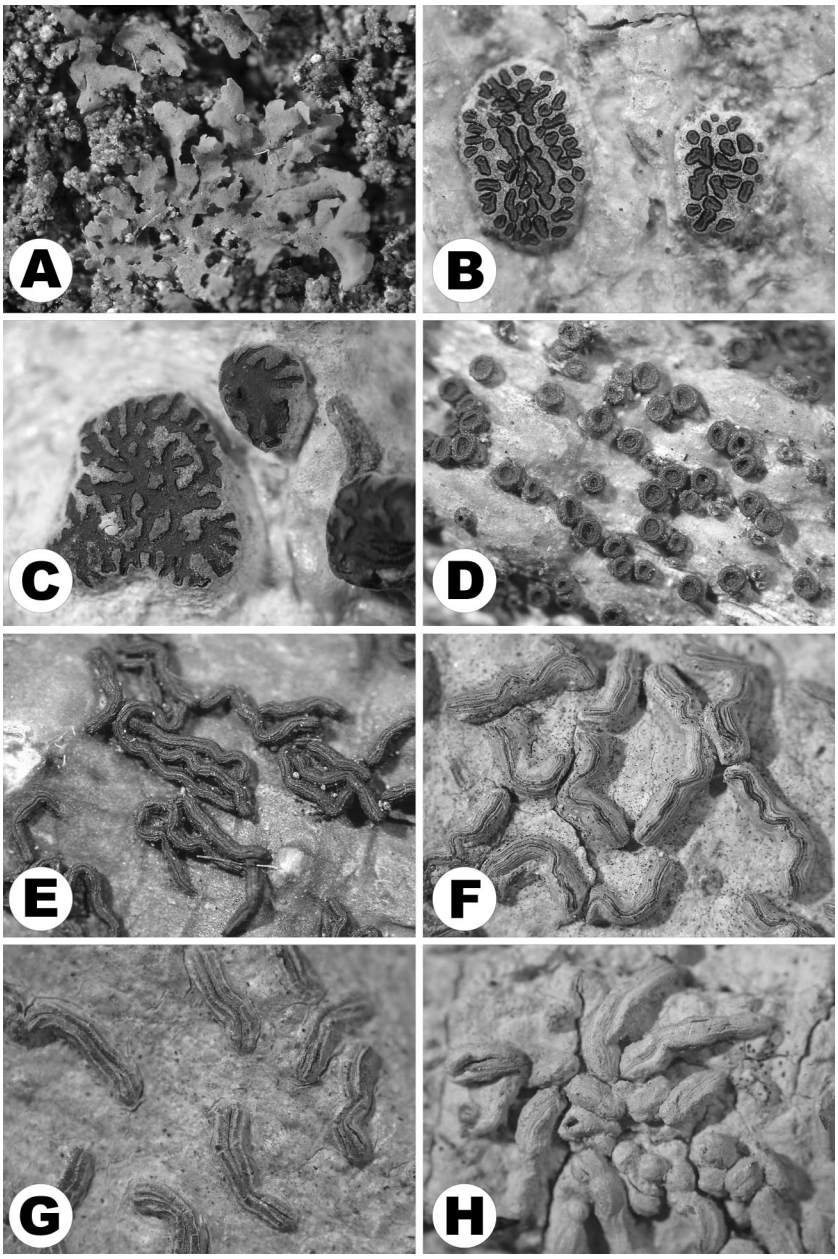
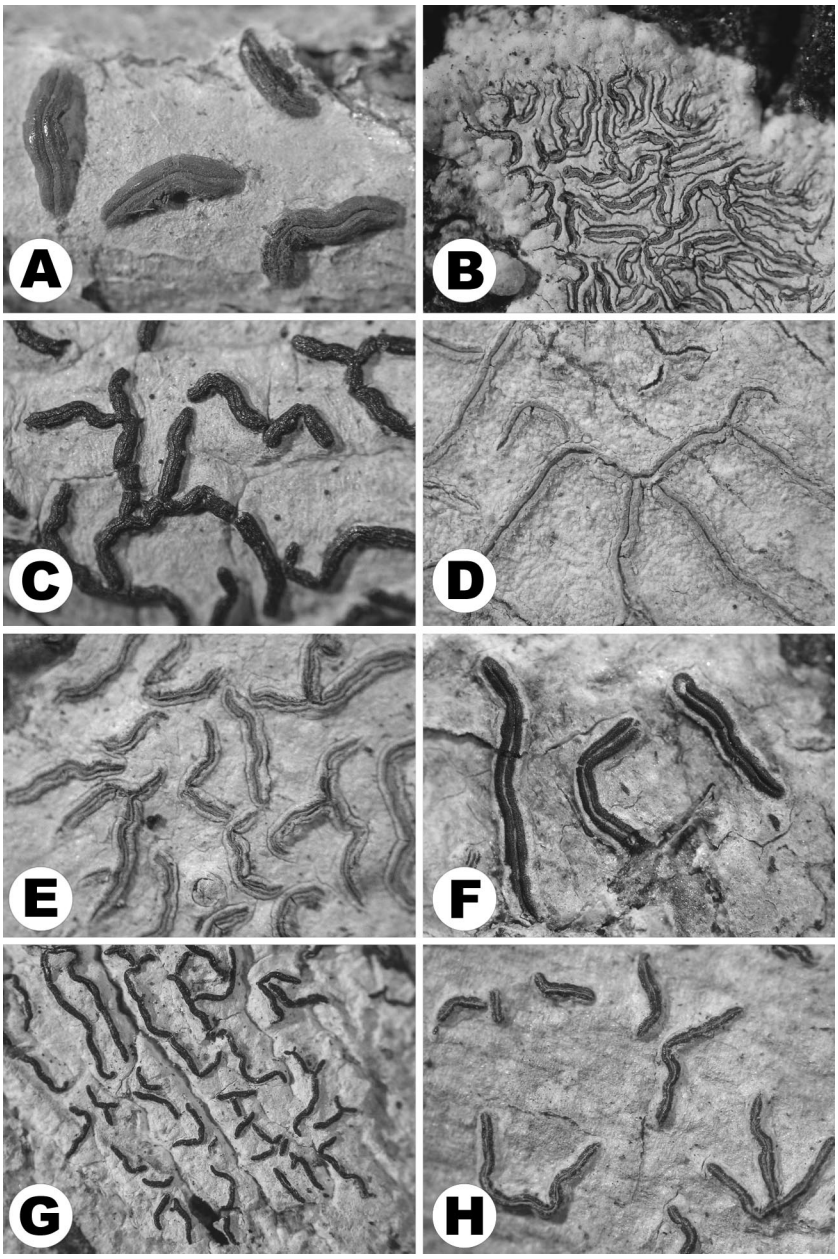


Figure 14: A. *Flakea papillata* [98-s.n.]; B-C. *Glyphis cicatricosa* [01-129]; D. *G. scyphulifera* [00-228]; E. *G. substriatula* [2097]; F. *Graphis acharii* [2057]; G. *G. argentea* [01-519]; H. *G.carassensis* [01-19].



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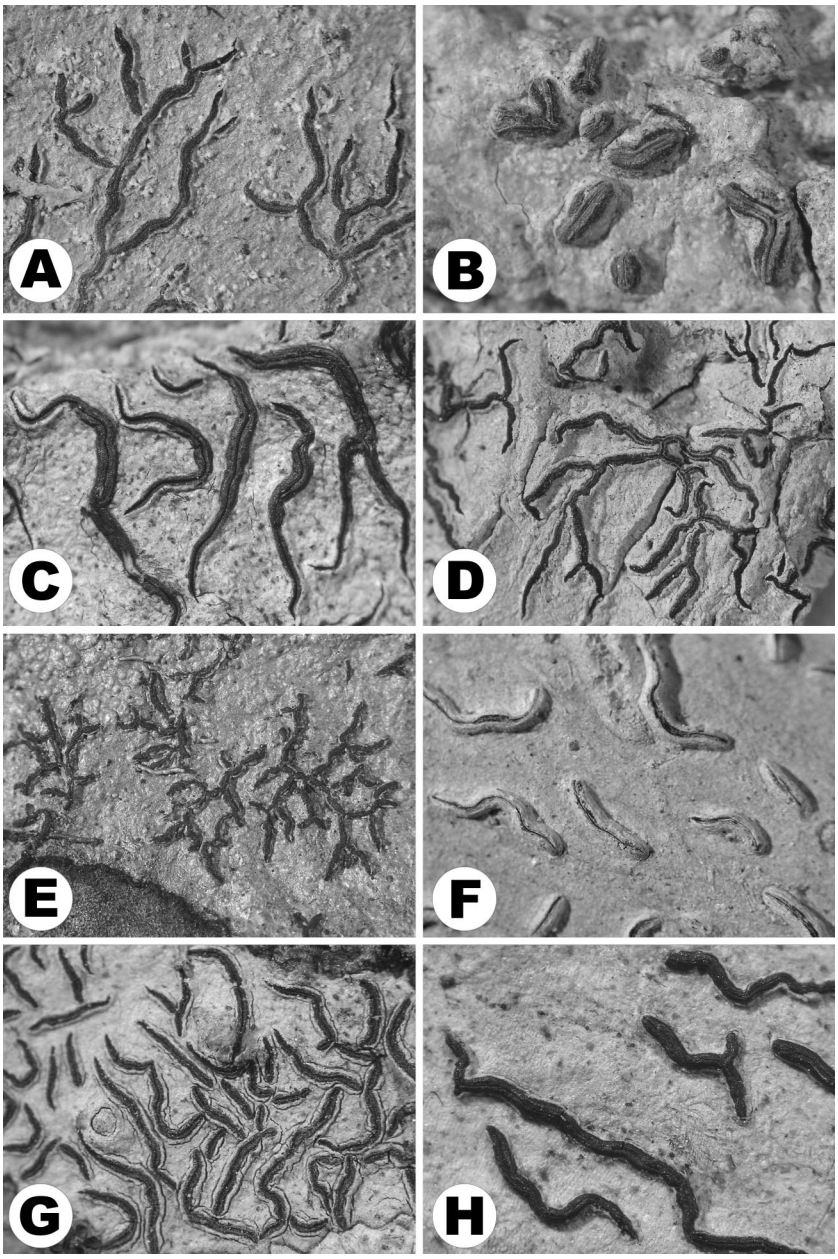

Figure 16: A. *Graphis pernambucoradians* [00-655]; B. *G. pilaresis* [01-514]; C. *G. rigidula* [00-240]; D. *G. schiffneri* [00-12]; E. *G. stellata* [s.n.]; F. *G. subturgidula* [2030a]; G. *G. tenella* [00-222]; H. *G. virescens* [00-549].

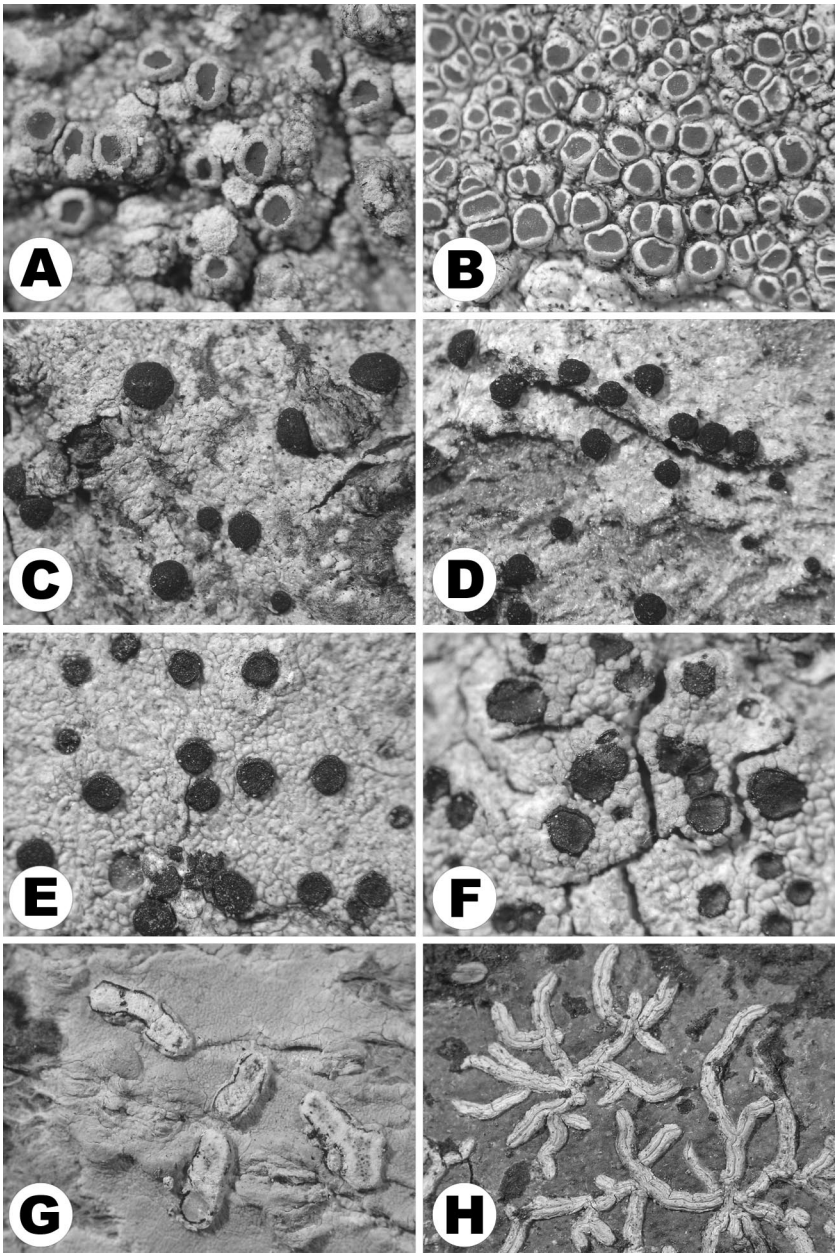

Figure 17: A. *Haematomma leprarioides* [01-18]; B. *H. personii* [2133]; C. *Hafellia bahiana* [01-513]; D. *H. curatellae* [00-68]; E. *H. demutans* [00-70]; F. *H. parastata* [00-129]; G. *Helminthocarpon leprevostii* [00-9]; *Hemithecium chrysentheron* [00-373].

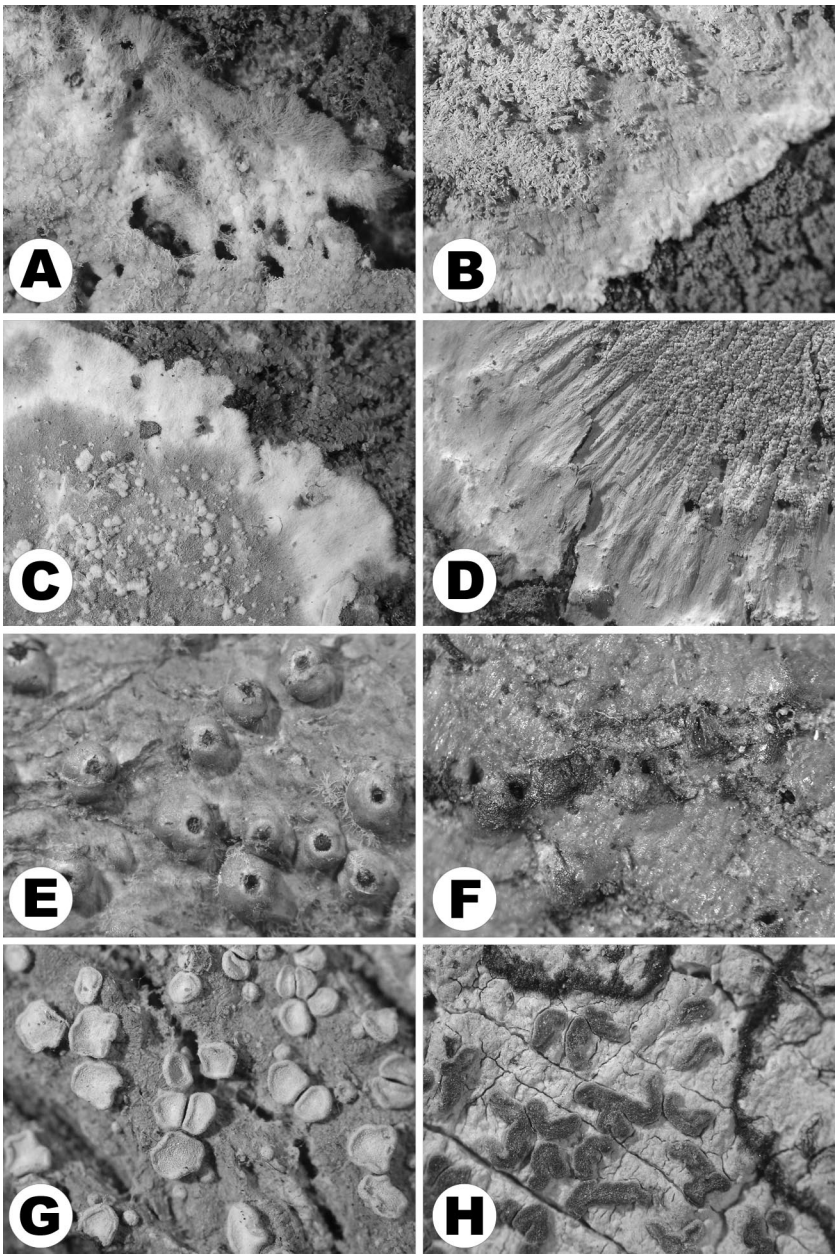

Figure 18: A. *Herpothallon* spec. A [00-285]; B. *H*. spec. B [01-504]; C. *H*. spec. D. [00-284]; D. *H. rubrocinctum* [00-286]; E. *Laurera megasperma* [00-628]; F. *L. sphaeroides* [00-629]; G. *Lecanactis epileuca* [A45-360]; H. *Lecanographa lyncea* [00-113].

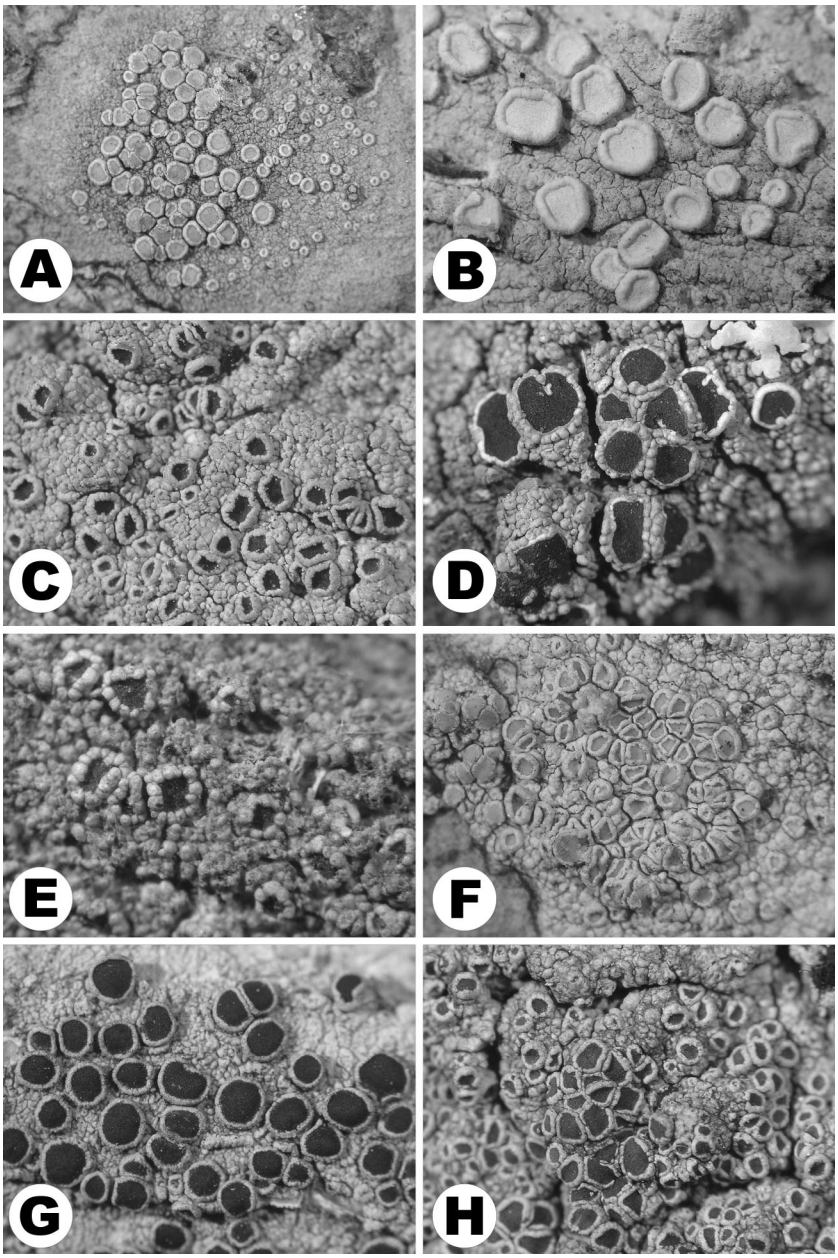

Figure 19: A. *Lecanora achroa* [00-67]; B. *L. caesiorubella* [00-86]; C. *L. concilianda* [00-231]; D. *L. concilians* [2178]; E. *L. coronulans* [00-295]; F. *L. helva* [98-s.n.]; G. *L. hypocrocina* [2136]; H. *L. tropica* [00-232].

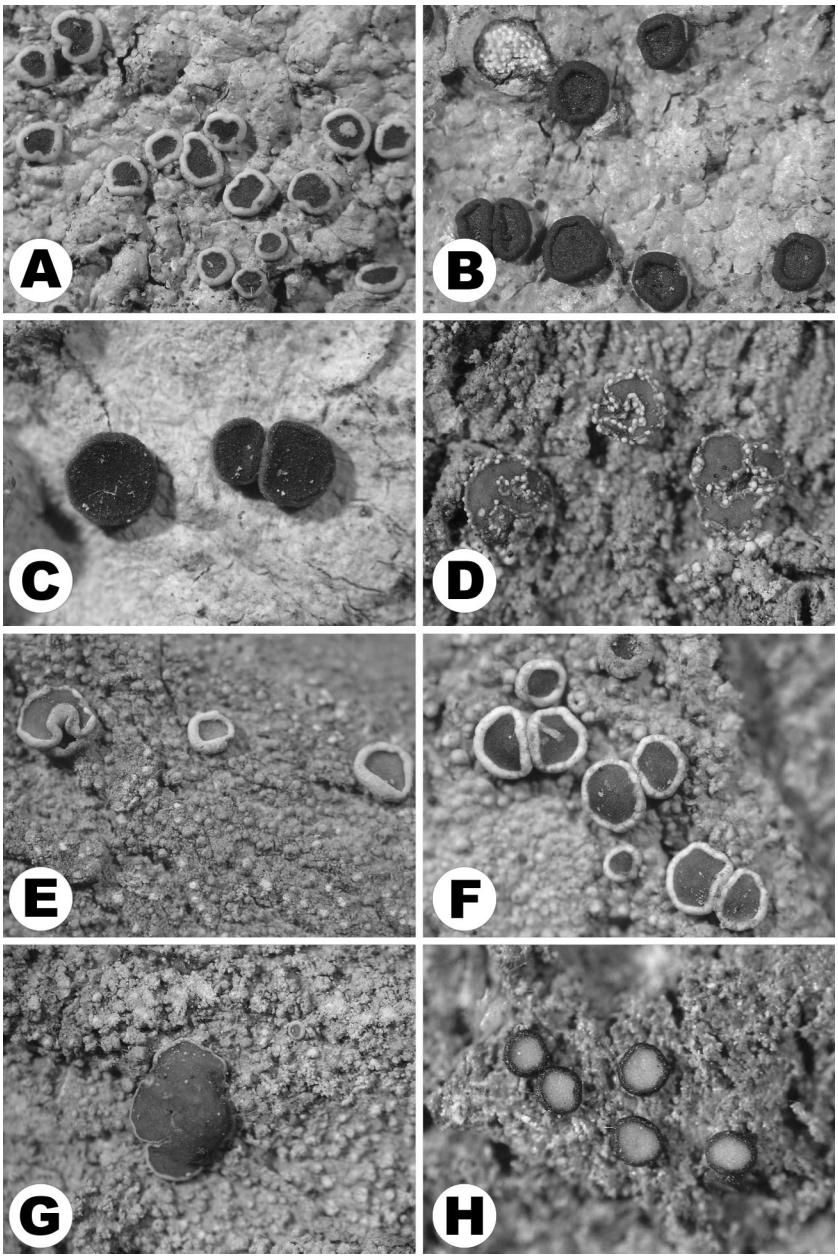

Figure 20: A. *Letrouitia dominguensis* [01-58]; B. *L. subvulpina* [A35-273]; C. *Lopezaria versicolor* [00-569]; D. *Malcolmiella* aff. *psychotrioides* [A41-322]; E. *M. atlantica* [00-828]; F. *M. badimioides* [01-159]; G. *M. flavopustulosa* [2011]; H. *M. furfurosa* [00-462].

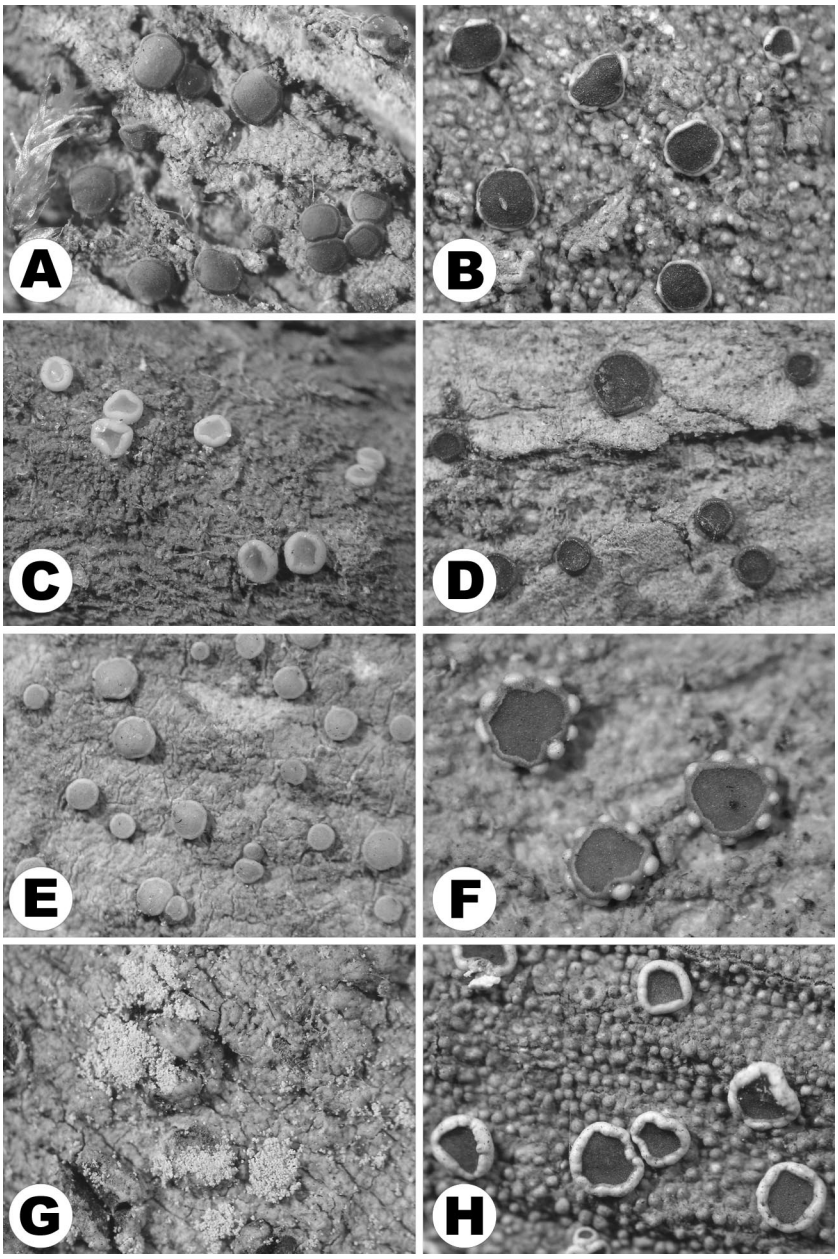

Figure 21: A. *Malcolmiella fuscella* [00-673]; B. *M. granifera* [01-172]; C. *M. gyalectoides* [00-682]; D. *M. hypomela* [00-587]; E. *M. leptoloma* [00-576]; F. *M. piperis* [00-588]; G. *M. polycampia* [A11-110]; H. *M. psychotrioides* [00-217].

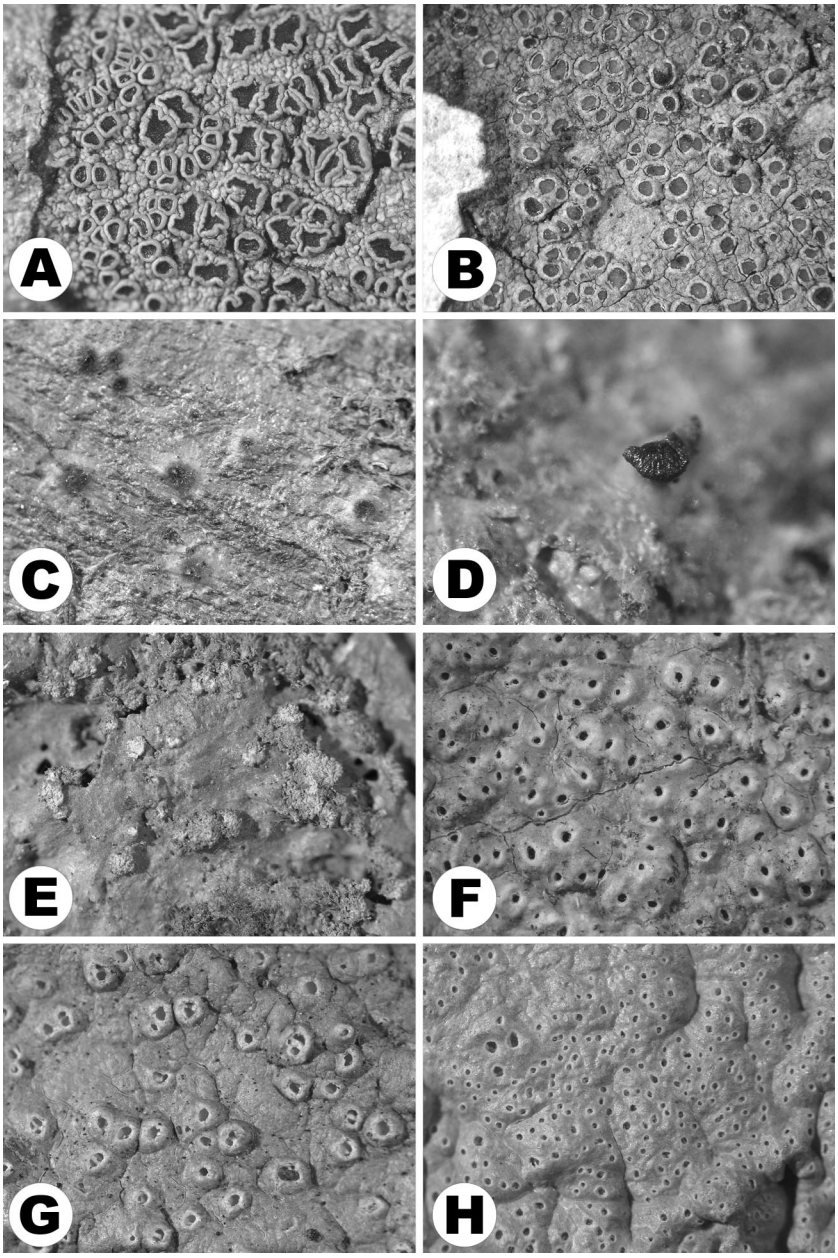

Figure 22: A. *Maronina multifera* [00-659]; B. *Mazosia ocellata* [2013]; C. *Musaespora epiphylla* [00-309]; D. *M. kalbii* [00-145]; E. *Myeloconis guyanensis* [00-324]; F. *Myriotrema congestum* [A8-70]; G. *M. glaucophaenum* [00-903]; H. *M. myrioporoides* [01-576].

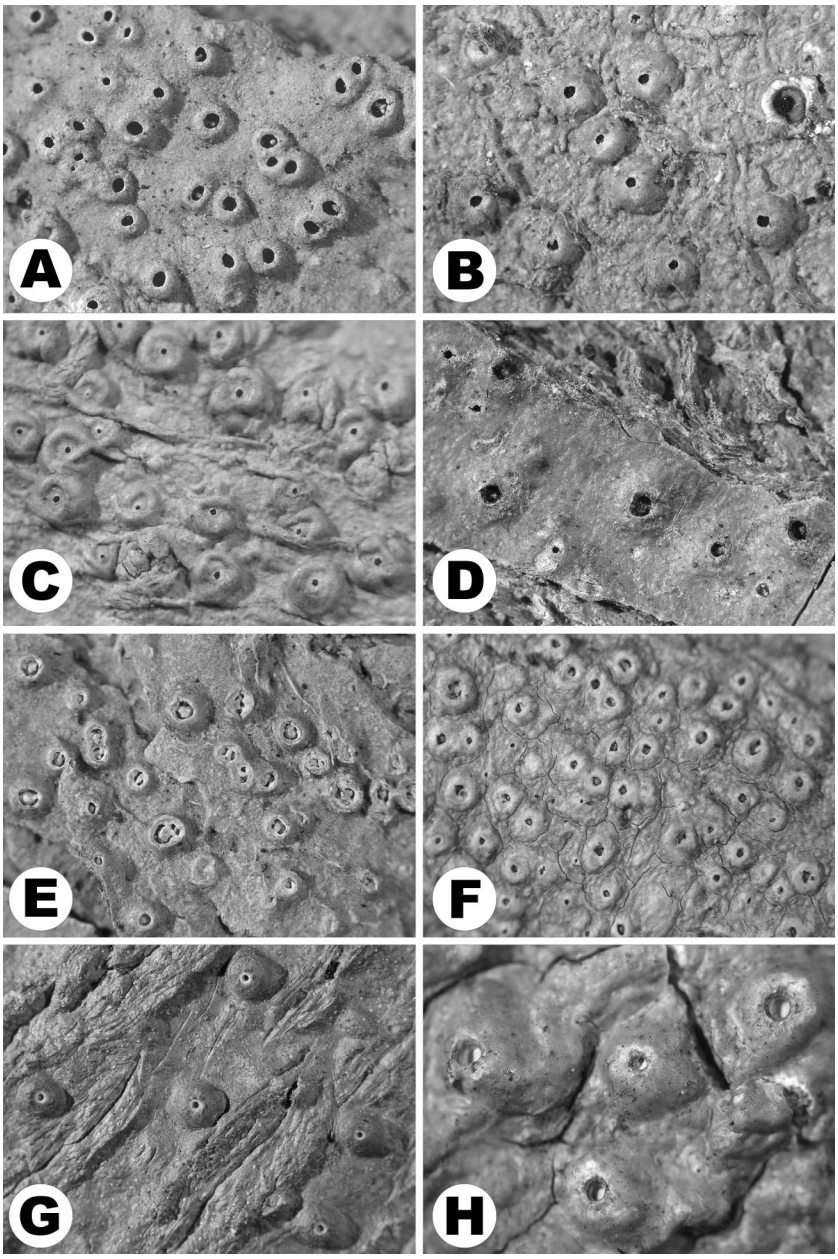

Figure 23: A. *Ocellularia bahiana* [01-600]; B. *O. cavata* [00-557]; C. *O. gracilis* [00-615]; D. *O. landronii* [01-105]; E. *O. mauritiana* [00-558]; F. *O. papillata* [01-171]; G. *O. praestans* [00-169]; H. *O.* aff. *praestans* [2063].

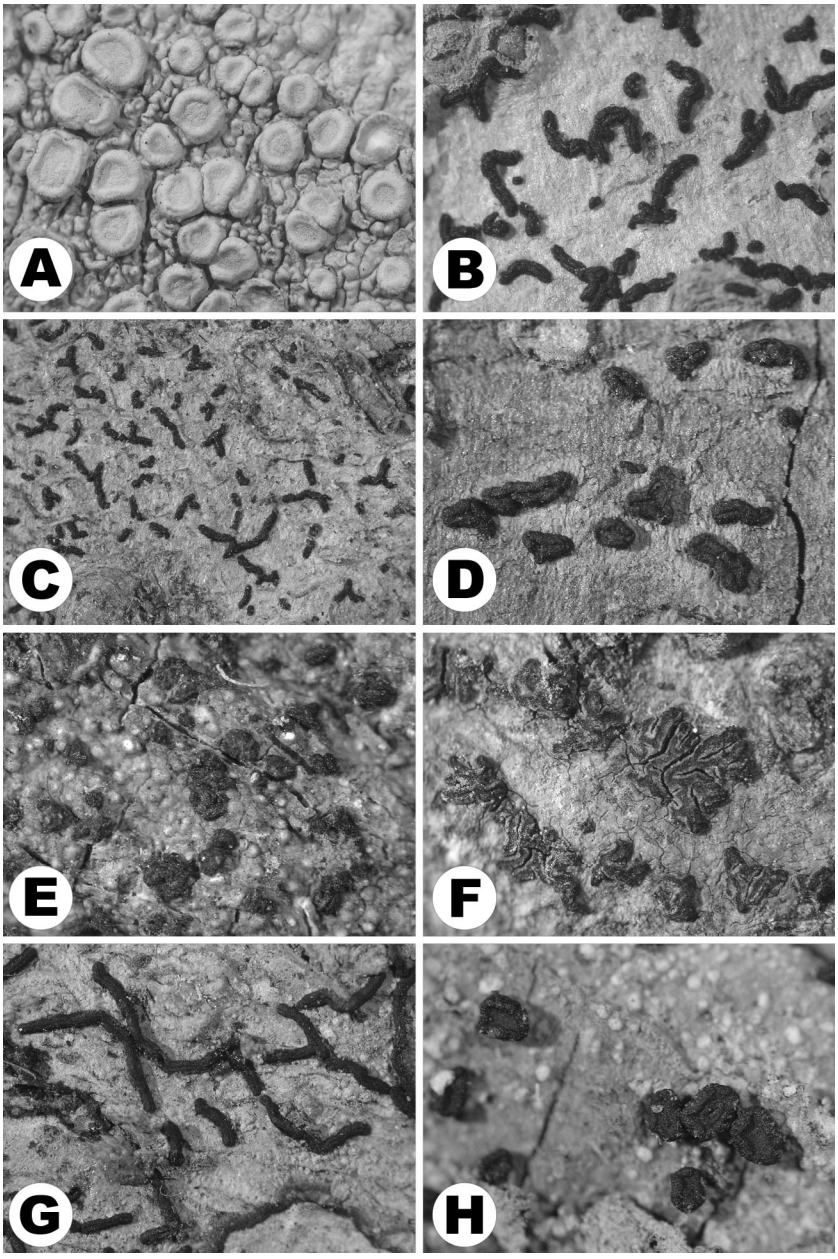

Figure 24: A. *Ochrolechia africana* [2094]; B. *Opegrapha* cf. *arengae* [00-500]; C. *O. atratula* [00-552]; D. *O.* aff. *contracta* [00-560]; E. *O.* cf. *millegrana* [00-507]; F. *O. quintana* [2210]; G. *O.* cf. *robusta* [00-845]; H. *O.* cf. *urosperma* [00-511].

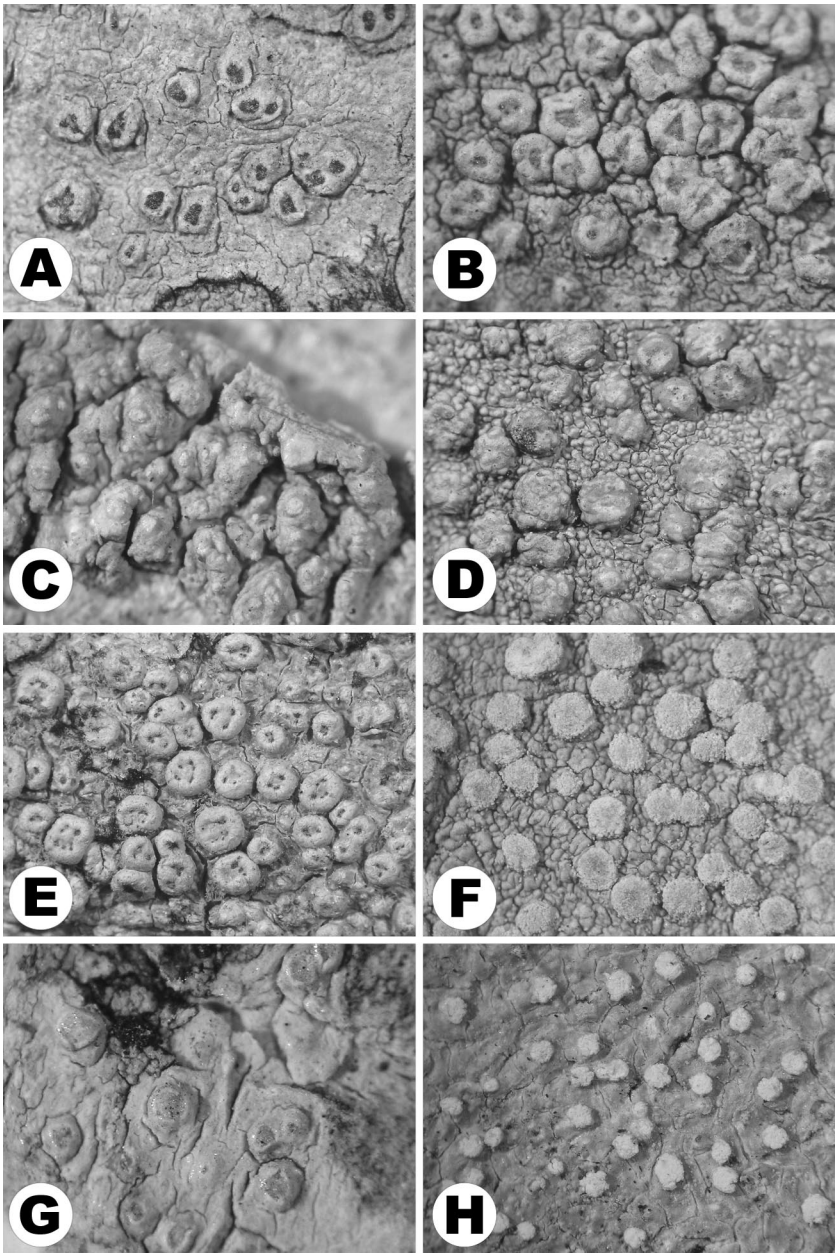

Figure 25: A. *Pertusaria carneola* [00-65]; B. *P. dehiscens* [00-28]; C. *P. flavens* [2117]; D. *P. quassiae* [00-27]; E. *P. tetrathalamia* [00-553]; F. *P. ventosa* [00-22]; G. *P. wulfenioides* [2111]; H. *P.* spec. [00-544].

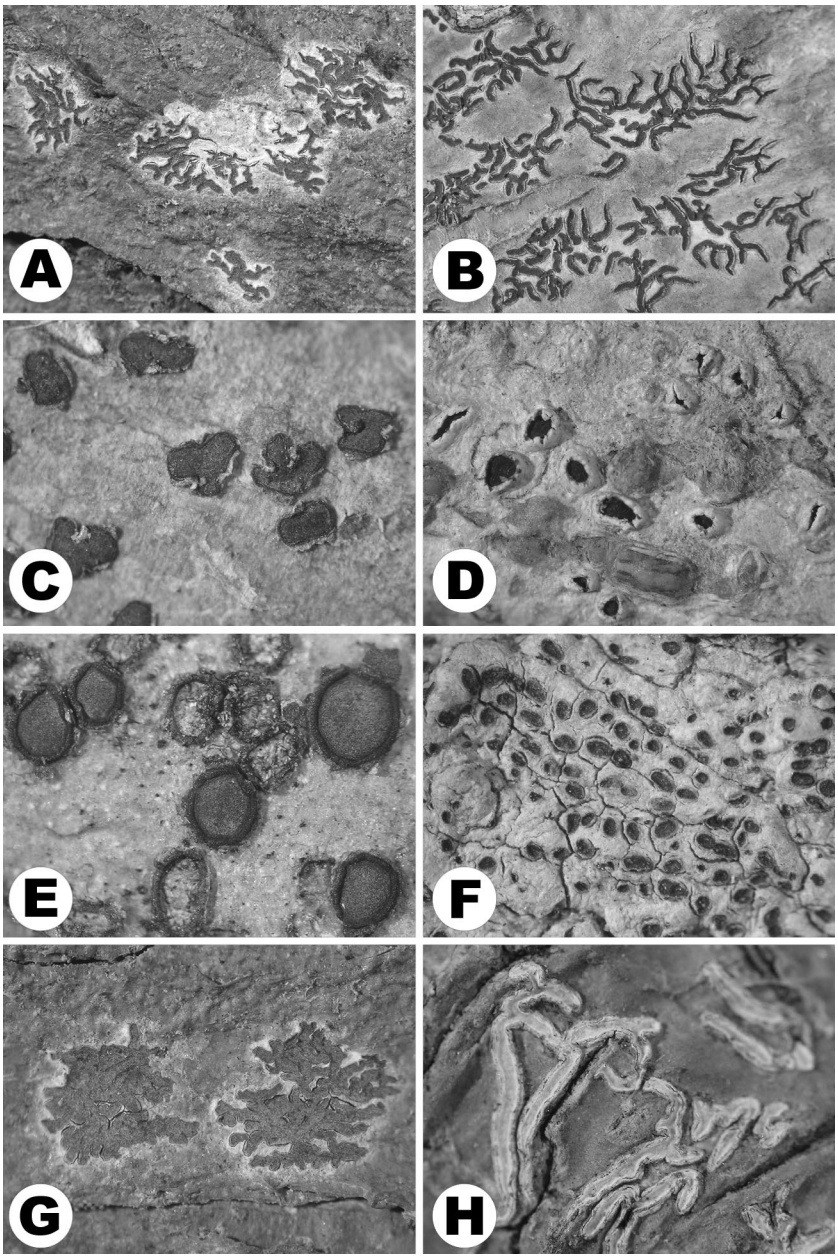

Figure 26: A. *Phaeographis brasiliensis* [00-634]; B. *P. crispata* [00-865]; C. *P.* aff. *fusca* [00-612]; D. P. kalbii [00-639]; E. *P. lobata* [00-618]; F. *P. punctiformis* [98-501]; G. *P. rubrostroma* [00-634]; H. *P. tortuosa* [01-07].

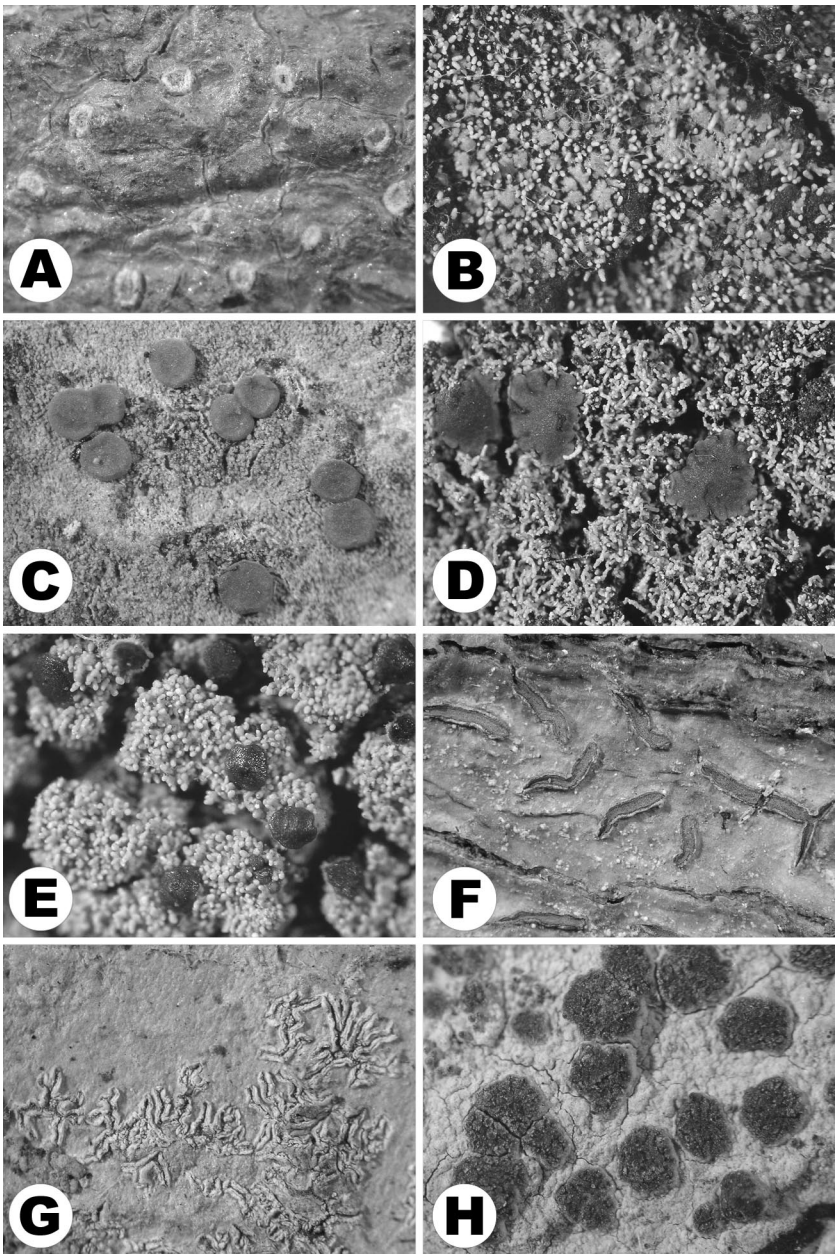

Figure 27: A. *Phlyctella brasiliensis* [00-294]; B. *Phyllopsora corallina* [2062]; C. *P. furfuracea* [A21-192]; D. *P. intermediella* [00-335]; E. *P. kalbii* [2169]; F. *Platygramme caesiopruinosa* [00-656]; G. *Platythecium dimorphodes* [00-398]; H. *Plectocarpon syncesioides* [A15-133].

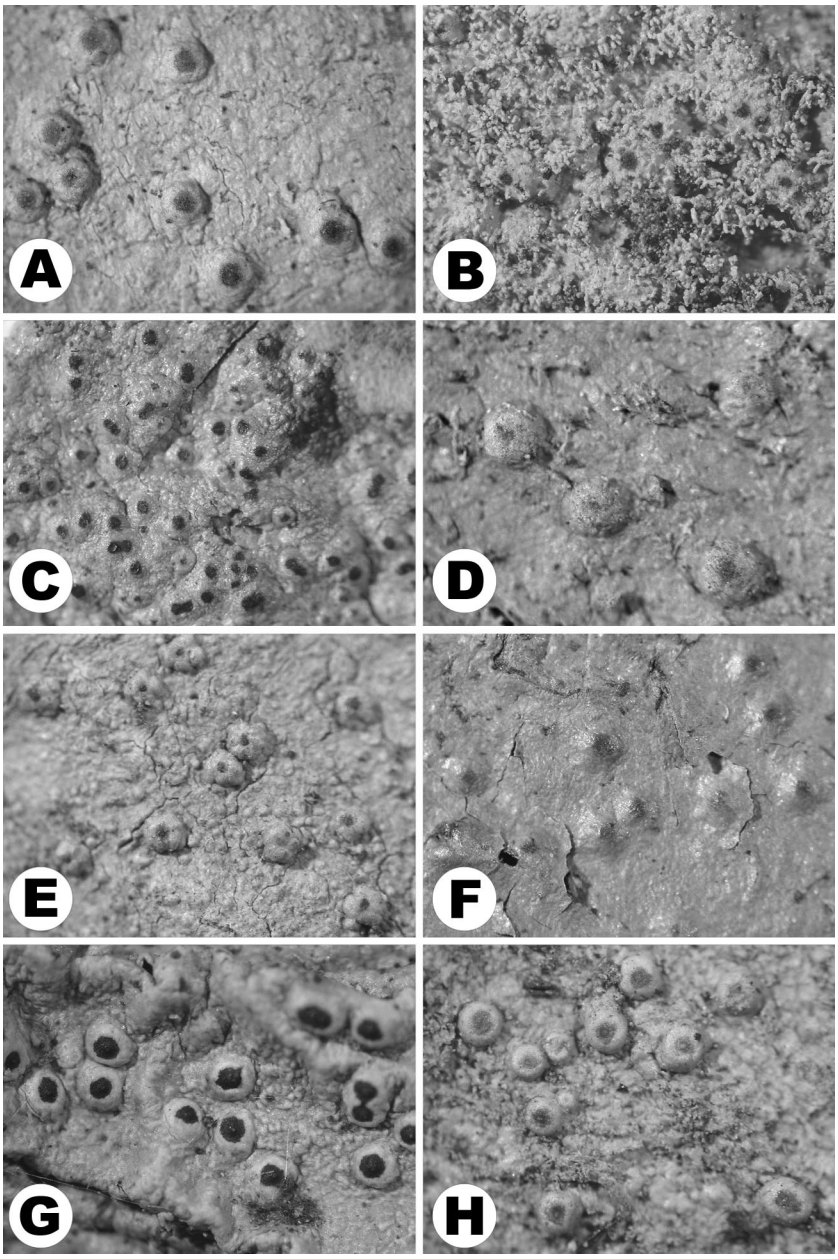

Figure 28: A. *Porina africana* [00-856]; B. *P. conspersa* [A8-62]; C. *P. curtula* [2004]; D. *P. farinosa* [01-539]; E. *P. guaranitica* [00-564]; F. *P. imitatrix* [00-566]; G. *P. mastoidea* [01-167]; H. *P. scabrida* [00-170].

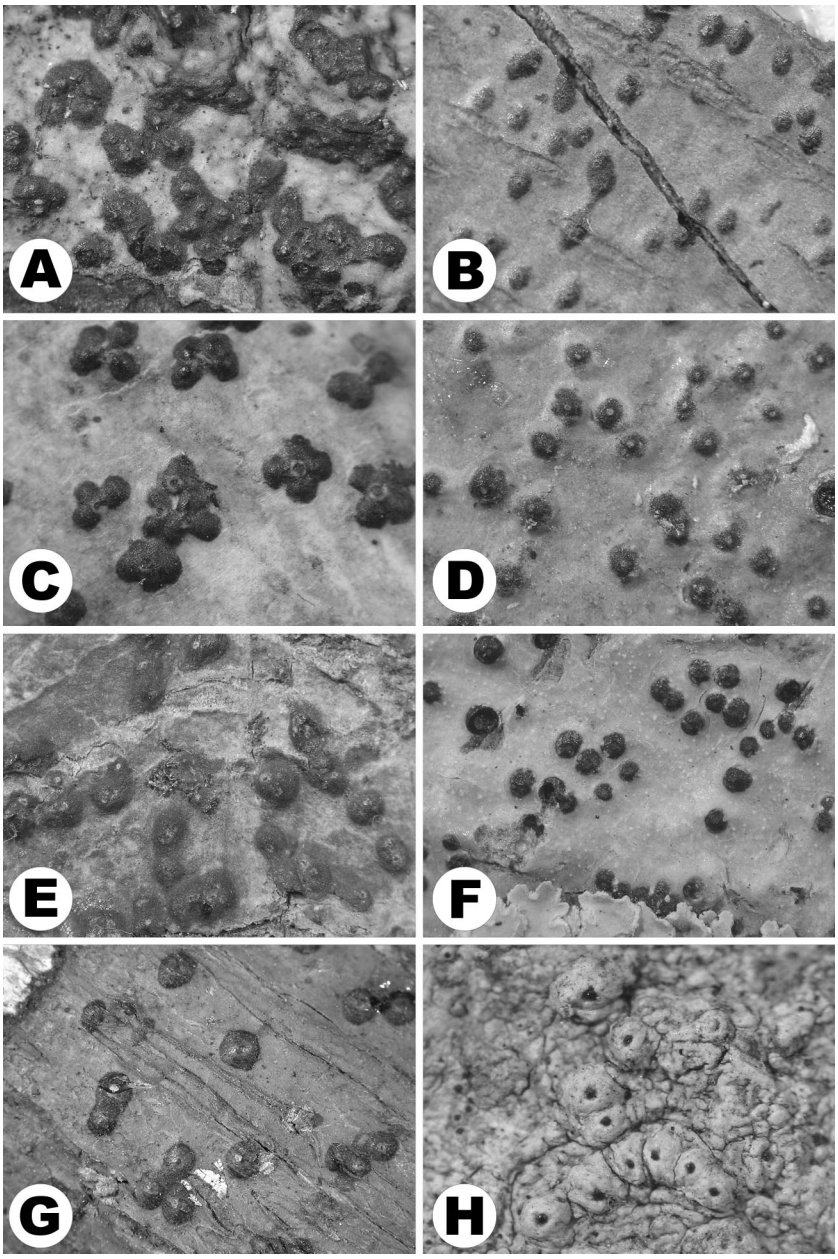

Figure 29: A. *Pyrenula anomala* [01-56]; B. *P. aspistea* [00-885]; C. *P. astroidea* [00-253]; D. *P. concatervans* [00-49]; E. *P. cruenta* [00-886]; F. *P. macularis* [98-601]; G. *P. mamillana* [00-180]; H. *P. micromma* [00-172].

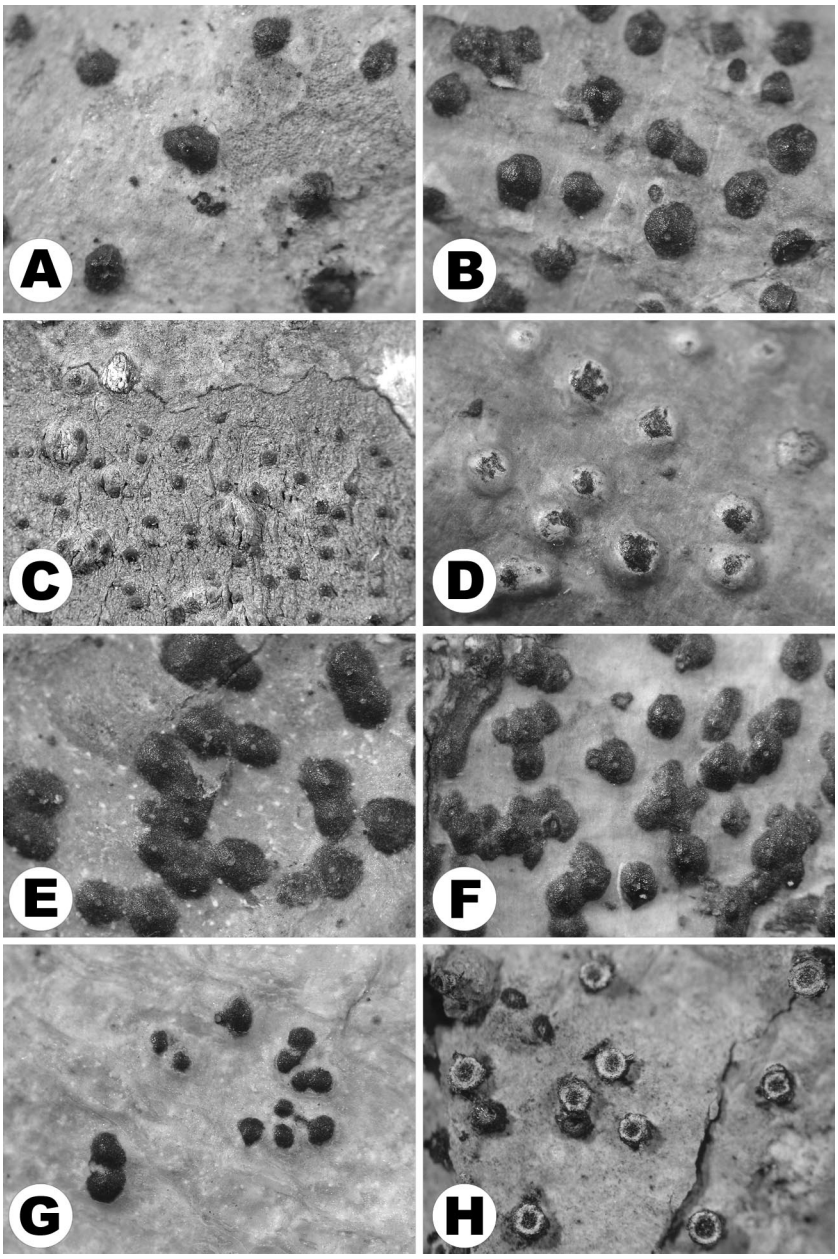

Figure 30: A. *Pyrenula mycrotheca* [A4-26]; B. *P. nitidula* [A21-185a]; C. *P. ochraceoflava* [00-34a]; D. *P. prelucida* [00-257]; E. P. *quassiaecola* [00-50]; F. *P. santensis* [00239]; G. *P. septicollaris* [00-46]; H. P. *Pyrgillus javanicus* [01-50].

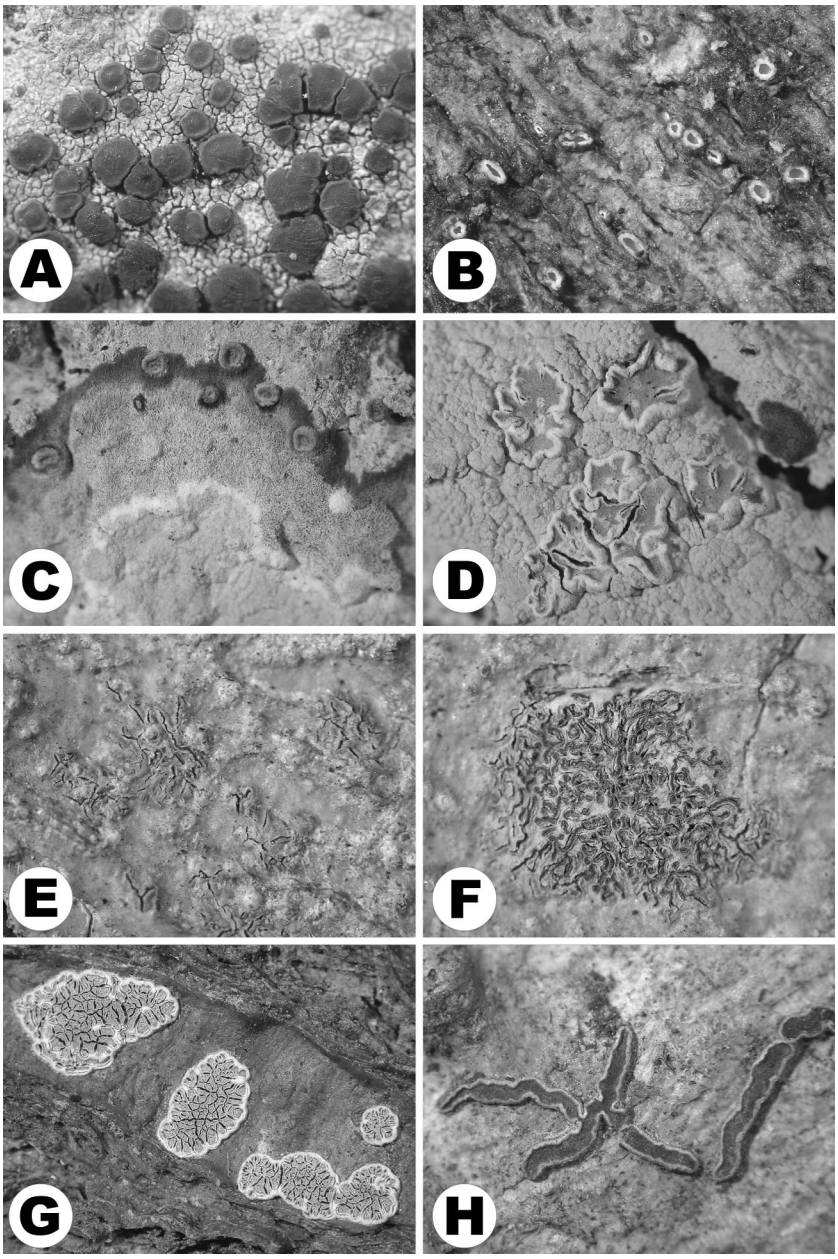

Figure 31: A. *Pyrrhospora haematites* [00-806a]; B. *Ramonia intermedia* [01-189b]; C-D. *Sagenidiopsis undulata* [00-265]; E-F. *Sarcographa fissurinoides* [01-516]; G. *S. labyrinthica* [01-21]; H. *S. ramificans* [00-156].

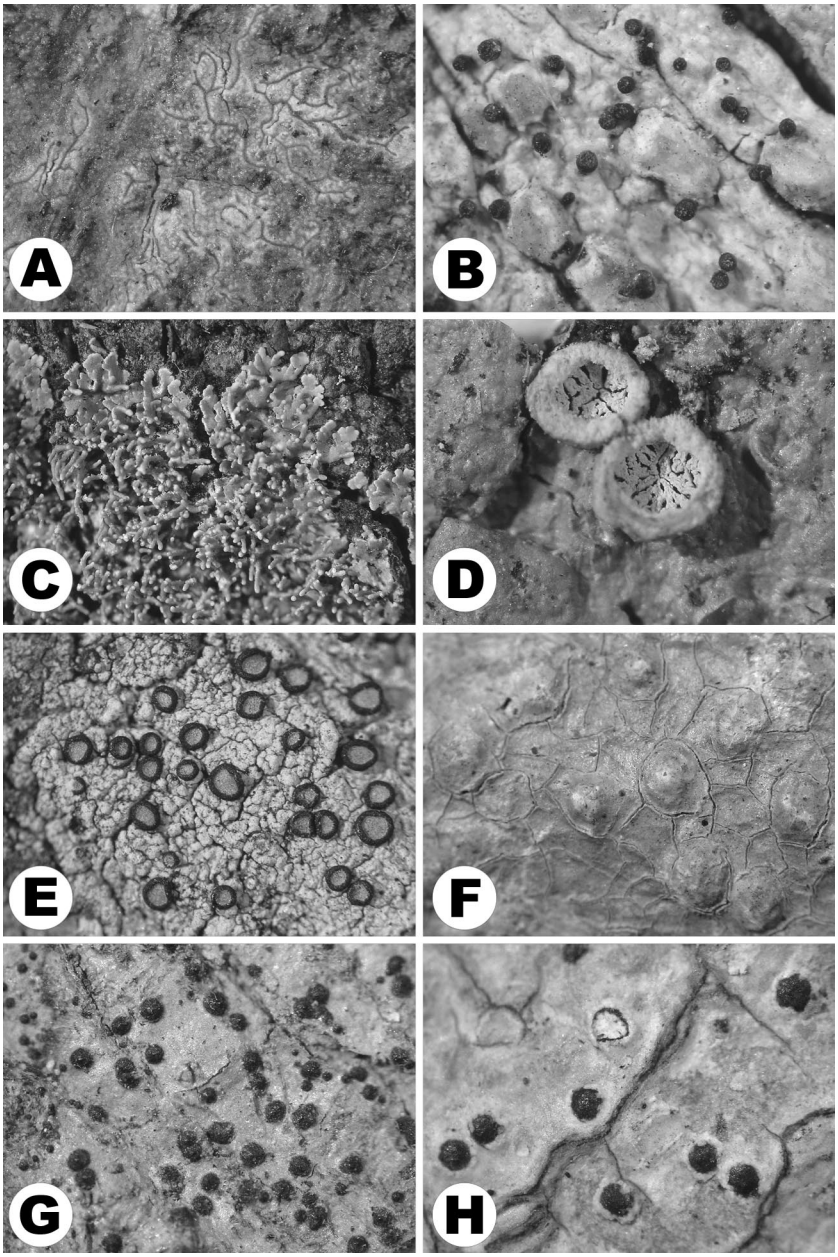

Figure 32: A. *Sclerophyton elegans* [A21-191]; B. *Sphinctrina tubiformis* [00-120b]; C. *Squamacidia janeirensis* [2023]; D. *Stegobolus wrightii* [2071]; E. *Stigmatochroma gerontoides* [2093]; F. *Strigula obtecta* [00-268]; G. *S. phaea* [00-182]; H. *S. viridiseda* [00-45].

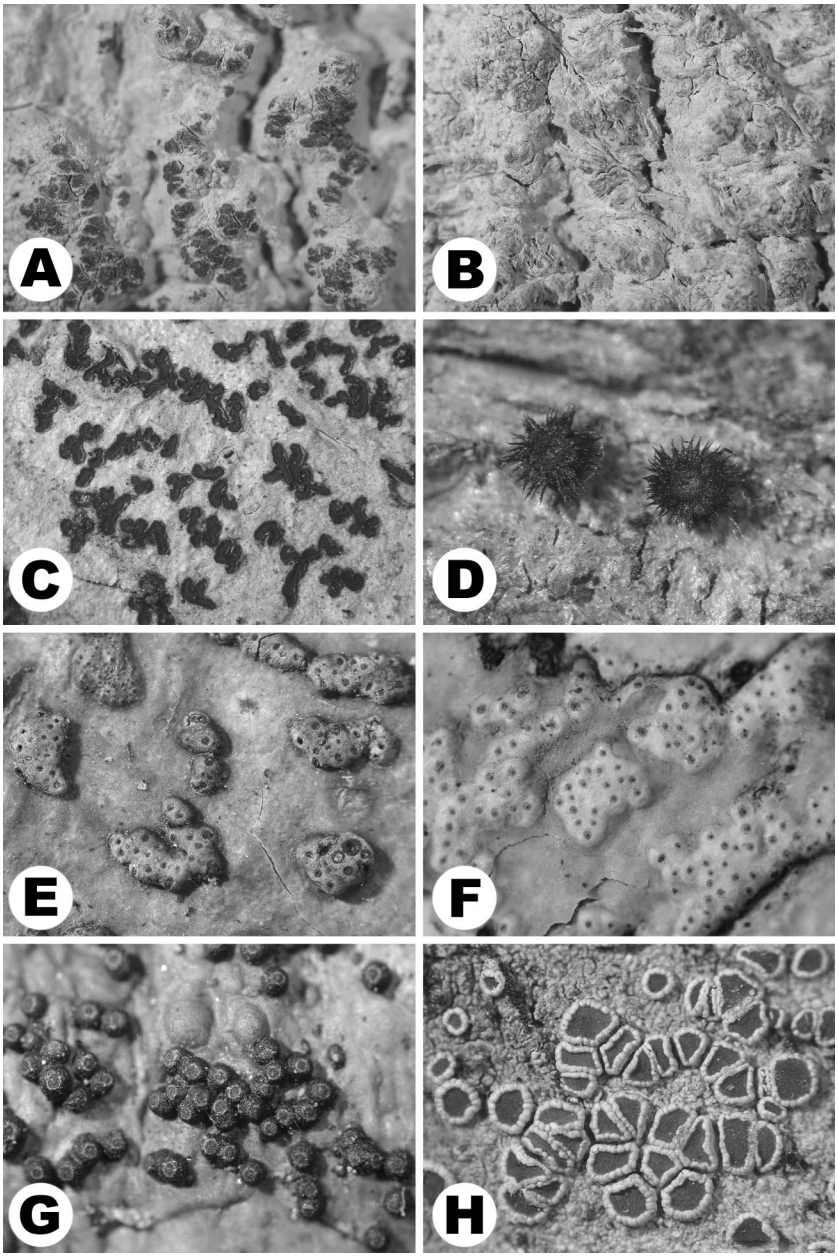

Figure 33: A. *Syncesia effusa* [01-02]; B. *S. rhizomorpha* [s.n.]; C. *Thalloloma astroideum* [00-640]; D. *Trichothelium horridulum* [00-279]; E. *Trypethelium eluteriae* [00-510]; F. *T. ochroleucum* [2028]; G. *T. tropicum* [2173]; H. *Vainionora flavovirens* [00-659].

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Corticolous microlichens in northeastern Brazil: Habitat differentiation between coastal Mata Atlântica, Caatinga and Brejos de Altitude

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Abstract. *As the outcome of a major inventory of the corticolous microlichen biota in 22 localities from north-eastern Brazil, a total of 456 species are reported, distributed among the three main vegetation types present at the study area: coastal Mata Atlântica, the Caatinga, and the Brejos de Altitude (rainforest enclaves in Caatinga areas). Non-metric multidimensional scaling (NMS) and cluster analysis based on Sørensen's coefficient of dissimilarity were applied to ordinate and classify sites according to the lichen species composition. Indicator species analysis for each area was performed by applying a Monte-Carlo test. Fifty-nine taxa were common between Zona da Mata and Brejos de altitude, 20 between Zona da Mata and Caatinga, and none between Brejos de Altitude and Caatinga. The dissimilarity values across Zona da Mata versus Brejos de Altitude sites are high (0.77 or 23% shared species on average) and across Zona da Mata versus Caatinga were even more pronounced (average of 0.92). Lichens in the Zona da Mata frequently had trentepohlioid photobionts ($p < 0.05$), while those in the Caatinga were associated with chlorococcoid photobionts ($p < 0.001$). Ascospores were predominantly transversely septate and/or narrow in lichens of the Zona da Mata (not significant), thick-walled or muriform ($p < 0.05$) and hyaline in those of the Brejos de Altitude, and megalosporous, non-septate and/or brown (all $p < 0.05$) in Caatinga species. Caatinga lichens also showed a highly significant predominance of atranorin, lichexanthone and other xanthones, as well as pulvinic acid derivates, as cortical substances, and norstictic acid as medullary substance.*

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Introduction

The Atlantic rainforest (Mata Atlântica) is one of the three major rainforest blocks in the neotropics (Whitmore 1990), in addition to the Central American rainforest and Choco, and the Amazon rainforest. Yet, more than 95% of the original vegetation cover of the Mata Atlântica in northeastern Brazil have been eliminated or are strongly affected by human activities, mainly due to agriculture (sugar cane plantations), logging, and the extension of urban areas like Recife and Salvador (Whitmore 1990; Silva Filho *et al.* 1998). One of the consequences of the extensive land use change, which has been taking place since the beginning of the Portuguese colonization in Brazil 500 years ago, is the increasing drought, which subsequently affects the already reduced and over-stressed rainforests remnants (Silva Filho *et al.* 1998; Cáceres *et al.* 2000).

The region of northeastern Brazil includes the states of Maranhão, Piauí, Ceará, Rio Grande do Norte, Paraíba, Pernambuco, Alagoas, Sergipe and Bahia. Of these, Rio Grande do Norte, Paraíba, Pernambuco, Alagoas, and Sergipe form the small northeastern coastal states focused upon in this study. The northeastern region comprises three main vegetation types: (1) the coastal Atlantic rainforest (Mata Atlântica or Zona da Mata), (2) the Caatinga (Sertão), and (3) the isolated montane Atlantic rainforest remnants within the Caatinga and the transitional (Agreste) vegetation, the so-called Brejos de Altitude (Andrade-Lima 1961, 1964; Rizzini 1977; Whitmore 1990; Marcelli 1998; Silva Filho *et al.* 1998). The Mata Atlântica covers a relatively narrow strip along the coast, extending from Rio Grande do Norte to southern Brazil (Rio Grande do Sul), where it becomes broader and covers the Serra da Mantiqueira, Serra do Mar and Serra do Espinhaço. In its northeastern part, it is characterized as a perennial forest with very pronounced dry season, while its southeastern part is more humid. The Caatinga is a very dry thorn-bush, in some parts desert-like vegetation, while the Brejos de Altitude are rainforest remnants, isolated from the coastal vegetation and located in the middle of the Caatinga, in areas of higher altitude (800–1000 m). As much as 95–98% of the total original area coverage of the Atlantic rainforest has been deforested in north-eastern Brazil, and many tree species have locally disappeared (FIDEM 1987; Ranta et al. 1998; Whitmore 1990; Cardoso Silva & Tabarelli 2000; Myers et al. 2000).

Hitherto, no comprehensive lichen inventory has been undertaken in northeastern Brazil, although the major vegetation types are assumed to have high lichen diversity, perhaps near to 1,000 species within the study region of Rio Grande do Norte to Sergipe. Barros & Xavier-Filho (1972) published a catalogue of lichens housed in the herbarium of the Federal University of Pernambuco in Recife (URM), but as a matter of fact, most of the lichen samples cited in this compilation derive from areas outside northeastern Brazil, including Europe, and came to the herbarium by exchange. Batista and collaborators made extensive collections of foliicolous lichens in the area (Silva & Minter 1995), but most of their identifications were found to be off and were corrected upon a recent revision (Lücking *et al.* 1999).

The most recent lichen inventory for this area, also including a thorough revision of the collections made by Batista and co-workers, covered foliicolous lichens only (Lücking *et al.* 1999; Cáceres *et al.* 2000). Except for a few large-scale monographic treatments (Harris 1986, 1989; Brako 1991; Kashiwadani & Kalb 1993; Tehler 1993; Staiger & Kalb 1995, 1999; Tibell 1996; Ahti 2000; Kalb *et al*. 2000, 2004; Staiger 2002; Sparrius 2004; Frisch *et al*. 2006) and scattered collections made chiefly by the German lichenologist Klaus Kalb (Kalb 1981, 1982a–d, 1983, 1984, 1987, 2001, 2004, 2007; Kalb & Elix 1995), little is known about the corticolous lichens of northeastern Brazil, in particular concerning corticolous crustose and microfoliose lichens.

Apart from the general lack of knowledge of the lichen biota, even less is known about the distribution and ecology of lichens within the study area. Such knowledge, however, is indispensable to assess the feasibility of using lichens as bioindicators of the impact of the ongoing land use change. Studies on foliicolous lichens already demonstrated their potential use as bioindicators of the impact of fragmentation on organismic diversity of the small and isolated Atlantic rainforest remnants in Pernambuco (Cáceres *et al.* 2000). It is assumed that corticolous microlichens can be used for the same purpose, since generally they show distinct habitat preferences in many species. While the knowledge of tropical lichen ecology is still rudimentary, recently a few quantitative studies were published including lichens in the Neotropics, including the montane rainforests of Colombia and Ecuador and the lowland rainforests and savannas of Venezuela and French Guiana (Cornelissen & Ter Steege 1989; Montfoort & Ek 1990; Wolf 1993; Komposch & Hafellner 1999, 2000, 2002; Nöske 2004; Nöske *et al.*

2004). Unfortunately, few of these went into the effort of identifying the bulk of the crustose lichens usually found in these habitats and making up a significant part of their diversity.

In northeastern Brazil, one recent, unpublished study dealt with the diversity of corticolous lichens in Atlantic rainforest remnants (Pereira *et al*. 2005a–c), but only a small part of these lichens was identified to species level and hence that study is of limited value to assess total lichen diversity and specific distribution patterns, and habitat preferences. The present paper is the first to examine the distribution of corticolous microlichens among the three principal vegetation zones in northeastern Brazil, based on the identification of a total of 446 crustose and microfoliose lichen species (Cáceres 2007)

Material and Methods

The statistical analyses were carried out using STATISTICA™ 6.0 and PC-ORD 4.0 (McCune & Mefford 1999).

For the comparative analysis of the crustose and microfoliose corticolous lichen biota in the three vegetation types in northeastern Brazil, a total of 22 localities (Fig. 1) was selected, representing the coastal Mata Atlântica or Zona da Mata (coastal rainforest), the Caatinga (with semi-arid climate and almost desert-like vegetation), and the Brejos de Altitude (rainforest patches in higher altitudes isolated within the middle of Caatinga areas). Among the 22 localities, 15 represent Mata Altlântica fragments in broader sense, located along the coastal Zona da Mata region. Collections from the Caatinga vegetation are represented here by five localities, while gatherings of Brejos de Altitude originate from two sites, both in Pernambuco state. One site was placed within the transitional Agreste region. A detailed account of the study area and the collecting sites is given elsewhere (Cáceres 2007; Cáceres *et al.* 2007a, b).

Non-quantitative opportunistic sampling was applied to each site as suggested by Sipman (1996). At each site, lichens were collected from tree bark along the main trail through the site. Trees were inspected within a 20 m broad strip along both sides of the corresponding trail, with a distance of about 10–20 m between each tree. About 50–100 trees were sampled at each site. Each lichen thallus recognized as potentially distinct in the field and which featured identifiable structures (ascomata, conidiomata, soralia, isidia, etc.) was collected, amounting to a total of 1–5(–10) thalli per tree and a total of 100–200(–300) specimens per locality (see also Cáceres *et al*. 2007b).

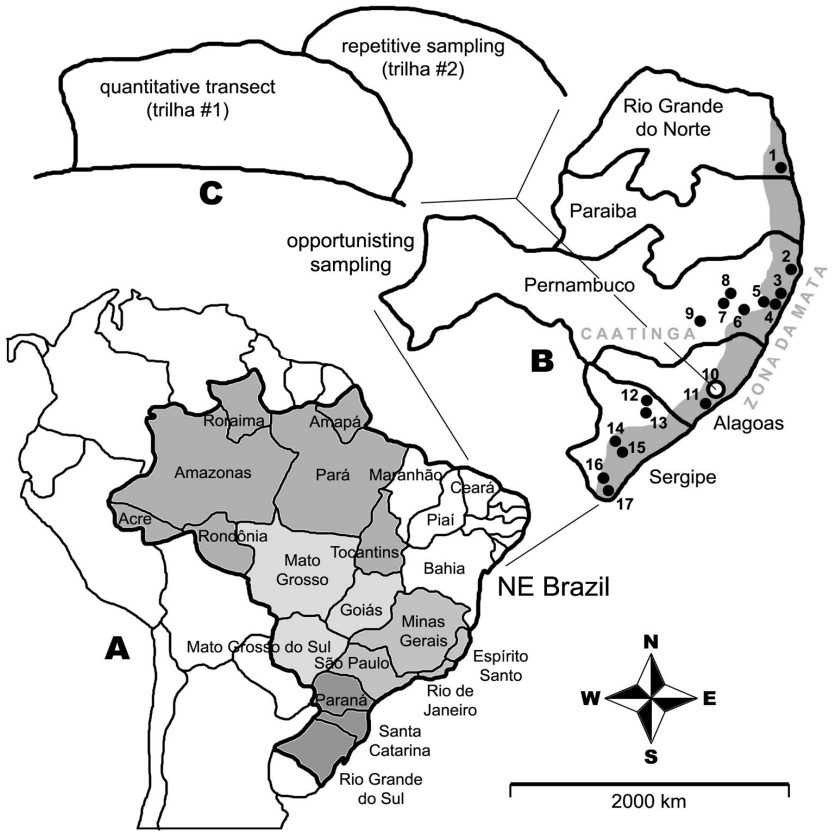

FIG. 1: Map of Brazil showing the five major geographic regions and the location of the study area and sites.

The procedures and literature used for the identification of the lichen material is given with detail in Cáceres (2007). Most lichen samples were duplicated, and three sets are deposited in URM (Herbário do Departamento de Micologia da Universidade Federal de Pernambuco), B (Botanical Garden & Botanical Museum Berlin-Dahlem) and F (Field Museum of Natural History, Chicago).

For the statistical analysis, each species was assigned an abundance vector for each site, based on the number of collections made: 0 = absent, 1 = rare (1–3 collections), 2 = intermediate (4–10 collections), and 3 = abundant (>10 collections). Alpha-diversity was calculated as the number of species per site, while gamma-diversity was calculated as the total number of species per vegetation type. Beta-diversity, that is dissimilarity between sites, was computed using the relative Sørensen coefficient of dissimilarity (McCune & Mefford 1999; McCune & Grace 2002).

Lichen species composition at each site was used to ordinate and classify sites by applying non-metric multidimensional scaling (NMS) as ordination method and cluster analysis based on the relative Sørensen coefficient of dissimilarity as classification method. NMS provides a two-dimensional projection of the sample points (localities) in the hyperdimensional lichen species space, by transforming their spacial coordinates into ranks and develop a two-dimensional projection through an iteration process (McCune & Mefford 1999; McCune & Grace 2002). A flexible beta = –0.25 was used as clustering algorithm; this

method results in similarly tight clusters as Ward's method but contrary to the latter is not incompatible with a distance matrix derived from Sørensen's coefficient of dissimilarity (McCune & Grace 2002).

Indicator species analysis was performed to detect species that can be classified as characteristic of a given vegetation type. For that purpose, a Monte-Carlo test was performed on the original frequency (number of sites where species was present) and abundance data (categorized number of collections per site), that is the data were mixed randomly with 1000 repetitions, and it was tested whether the observed data distribution deviated significantly from the random distribution derived from the Monte-Carlo test, i.e. whether a given species was significantly more abundant and frequent within a given vegetation type than expected by random (McCune & Grace 2002).

Lichen species unique to each of the three major vegetation types (Atlantic rainforest, Brejos de Altitudes and Caatinga) were used to test whether the observed frequency of selected character states (systematic affinity, morphology, anatomy, chemistry) among vegetation types differed significantly from the expected frequency based on the overall frequency of the character state. Observed versus expected frequencies were compared within each vegetation type across all states of a given character, and a Chi-Square test was used to determine statistical significance of the observed differences. Twelve characters were used with different sets of character states as defined in Table 04.

Results

Patterns of alpha-, beta, and gamma-diversity

A total of 456 species of corticolous crustose and microfoliose lichens were found in the three vegetation types in northeastern Brazil altogether. A complete checklist and taxonomic treatment for the reported taxa is published elsewhere (Cáceres 2007). The number of species per site varied from three to 99 (Fig. 2). The site with the highest number of species was the repetitively sampled RPPN Fazenda São Pedro in the state of Alagoas. The highest species numbers for opportunistically sampled sites were found for those representing Brejos de Altitude, which contributed 84 (Brejo dos Cavalos) and 73 species (Parque Municipal de Bonito), respectively. Sites within the Zona de Mata had slightly lower species numbers, the richest being the Refúgio Ecológico Charles Darwin (71) and the Estação Ecológica de Gurjaú (60) in the state of Pernambuco. The small rainforest remnant at Barragem near Gurjau had only eight taxa. The two Zona da Mata fragments situated at higher altitudes, Serra de Itabaiana and Fazenda São José, had 5–20 taxa. The three sites of exposed secondary vegetation within the Zona da

Mata, namely the RPPN Rosa do Sol, the UFPE Campus, and the exposed secondary vegetation at Gurjaú, showed little variation in the number of species (16–19), while only eight taxa were found at the exposed secondary vegetation near Brejo dos Cavalos. Only one site, Estação Ecológica de Tapacurá, was located in the transitional Agreste region; it had 22 species. Within the Caatinga, the number of species varied from 23 to 54 per site, with the largest number reported for the most conserved Caatinga vegetation at the IPA in Caruaru. The two sites representing exposed secondary Caatinga area, Garanhuns and the exposed secondary vegetation at the IPA, had 3–12 species.

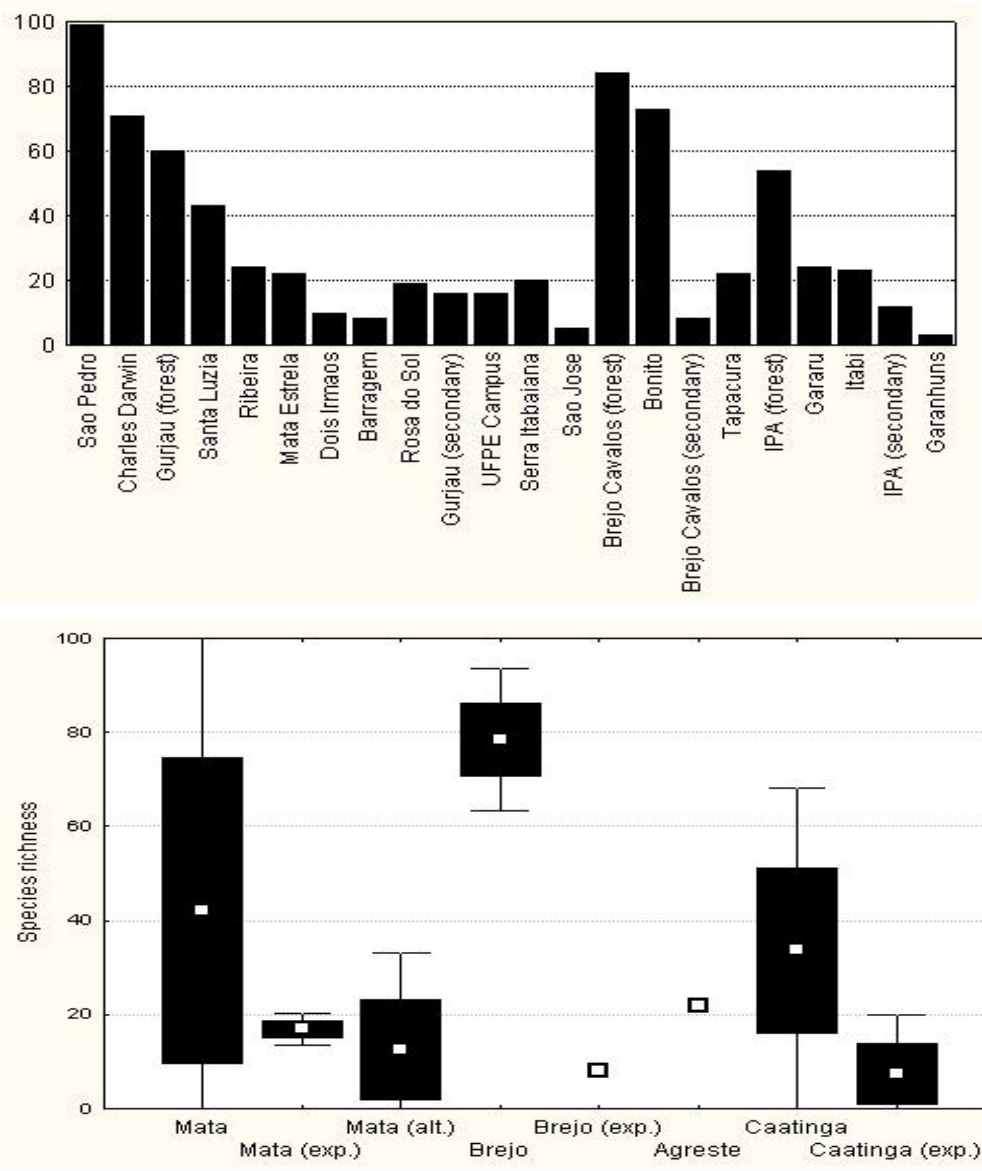

FIG. 2. Number of lichen species per site. Sites arranged according to major vegetation types and their anthropogenic variations and from high to low values.

When combining all sites within each of the three main vegetation types and their anthropogenic variations, the Zona da Mata understory sites yielded a total of 281 species, being the most diverse of the three vegetation zones altogether (Fig. 3). For the exposed secondary Zona da Mata sites and the higher altitude Zona da Mata forests, 43 and 25 taxa were found in total, and the combined number for the Zona da Mata sites was 334. The Brejos de Altitude localities represented the second most diverse region of the study area, with a total of 136 species. The three sites representing Caatinga vegetation comprised a total of 79 species, and the two exposed secondary Caatinga sites yielded 15 taxa, totalizing 84 species for all five Caatinga sites.

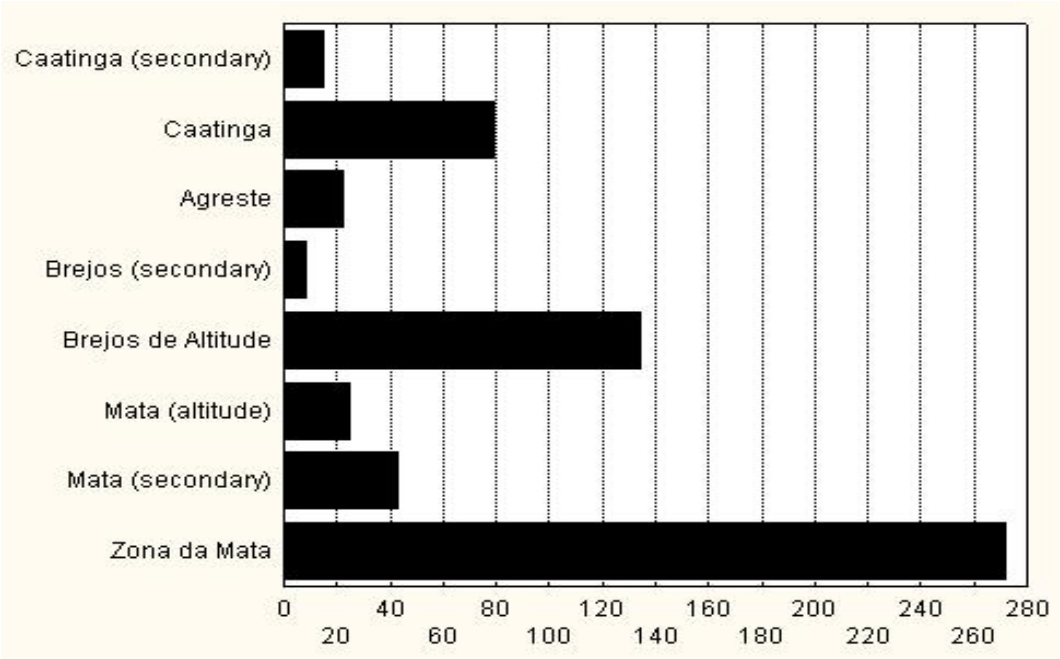

FIG. 3. Combined number of lichen species for the three main vegetation types and their anthropogenic variations.

Beta-diversity (Sørensen dissimilarity) in lichen species composition between any two sites was relatively high, with values ranging between 0.41 and 1.00 and a mean of 0.79 (Table 1). In other words, any two sites shared between 0% and 59% of the species only, with a mean of 21%. When comparing Zona da Mata sites only, the smallest dissimilarity value between any two sites was 0.45, which means that a maximum of 55% of the species was shared between any two sites and for all pairwise comparisons there were only 22% of the species in common on average. The two sites representing Brejos de Altitude had a dissimilarity of 0.56, meaning that they shared 44% of the

species. With respect to the three collecting sites located within the Caatinga, the smallest dissimilarity was 41% and the highest 83%, which means only 17–59% of the species were shared between sites. Although mean similarity was highest between Brejos de Altitude sites and lowest between Zona da Mata sites, the differences were not statistically significant (Kruskal-Wallis ANOVA).

TABLE 1. Sørensen dissimilarity and percentage of similarity between sites (ranges and mean), arranged according to the three main vegetation types and their anthropogenic variations.

Vegetation type	Dissimilarity (range)	Dissimilarity (mean)	Similarity (range)	Similarity (mean)
Zona da Mata (0–100 m)	0.45–1.00	0.78	0–55%	22%
Zona da Mata (0–100 m exposed)	0.67–0.85	0.75	15–33%	25%
Zona da Mata (300–500 m)	—	1.00	—	0%
Brejos de Altitude	—	0.56	—	44%
Caatinga	0.41–0.83	0.64	17–59%	36%
Caatinga (exposed)	—	0.72	—	28%
All sites	0.41–1.00	0.79	0–59%	21%

When comparing sites across the three main vegetation types, the dissimilarity values across Zona da Mata versus Brejos de Altitude sites were found to be relatively high, with an average value of 0.77 or 23% shared species (Table 2). Differences in species composition across Zona da Mata versus Caatinga were even more pronounced, with dissimilarity values averaging 0.92. Similarly high dissimilarity values were found across sites representing Brejos de Altitude and Caatinga. While the average similarity across Zona da Mata versus Brejos de Altitude is not different from the average between Zona da Mata sites (23% vs. 22%) and the average for all sites (21%), similarity across Zona da Mata and Brejos de Altitude versus Caatinga is significantly lower (8% vs. 22%, 44%, and 36%, respectively). This indicates that Caatinga lichen communities are more distinct from Zona da Mata and Brejos de Altitude communities than Brejos de Altitude from Zona da Mata communities.

TABLE 2. Sørensen dissimilarity and percentage similarity between sites (ranges and mean), comparing sites across the three main vegetaiton types.

Vegetation type	Dissimilarity (range)	Dissimarity (mean)	Similarity (range)	Similarity (mean)
Zona da Mata vs. Brejos de Altitude	0.57–1.00	0.77	0–43%	23%
Zona da Mata vs. Caatinga	0.69–1.00	0.92	0–31%	8%
Caatinga vs. Brejos de Altitude	0.87–0.98	0.92	2–13%	8%
All sites	0.41–1.00	0.79	0–59%	21%

Ordination and classification of sites

The NMS (non-metric multidimensional scaling) ordination, which is based on lichen species composition at each site, reveals a distinct pattern reflecting the three main vegetation types and their anthropogenic variations, with two main groups (Figure 4). One group includes all sites representing the understory of the humid Zona da Mata and Brejos de Altitude vegetation, while the other group comprises the exposed Zona da Mata and Brejos de Altitude sites and all the Caatinga sites, suggesting that lichen species composition of exposed rainforest sites resembles that of Caatinga sites rather than shady rainforest sites.

The first group can be divided in two subgroups: the Brejos de Altitude sites on one hand and the Zona da Mata sites on the other. Note that the two Zona da Mata sites at higher altitudes (300–500 m) do not form a separate group and also do not group with the Brejos de Altitude sites, indicating that their lichen species composition is different from the latter and more typical of lowland Zona da Mata sites. The site of the Agreste region (Tapacurá) falls intermediate between the Zona da Mata and the Caatinga sites, reflecting its transitional character. The second group is can be divided into three subgroups: one including the exposed secondary sites representing Zona da Mata, one representing the Caatinga sites, and one comprising the exposed Caatinga sites. The last two are more proximate to each other. Interestingly, the open Mata Atlântica and Brejos sites do not group with the closed Mata Atlântica sites but instead are proximate to the Caatinga sites.

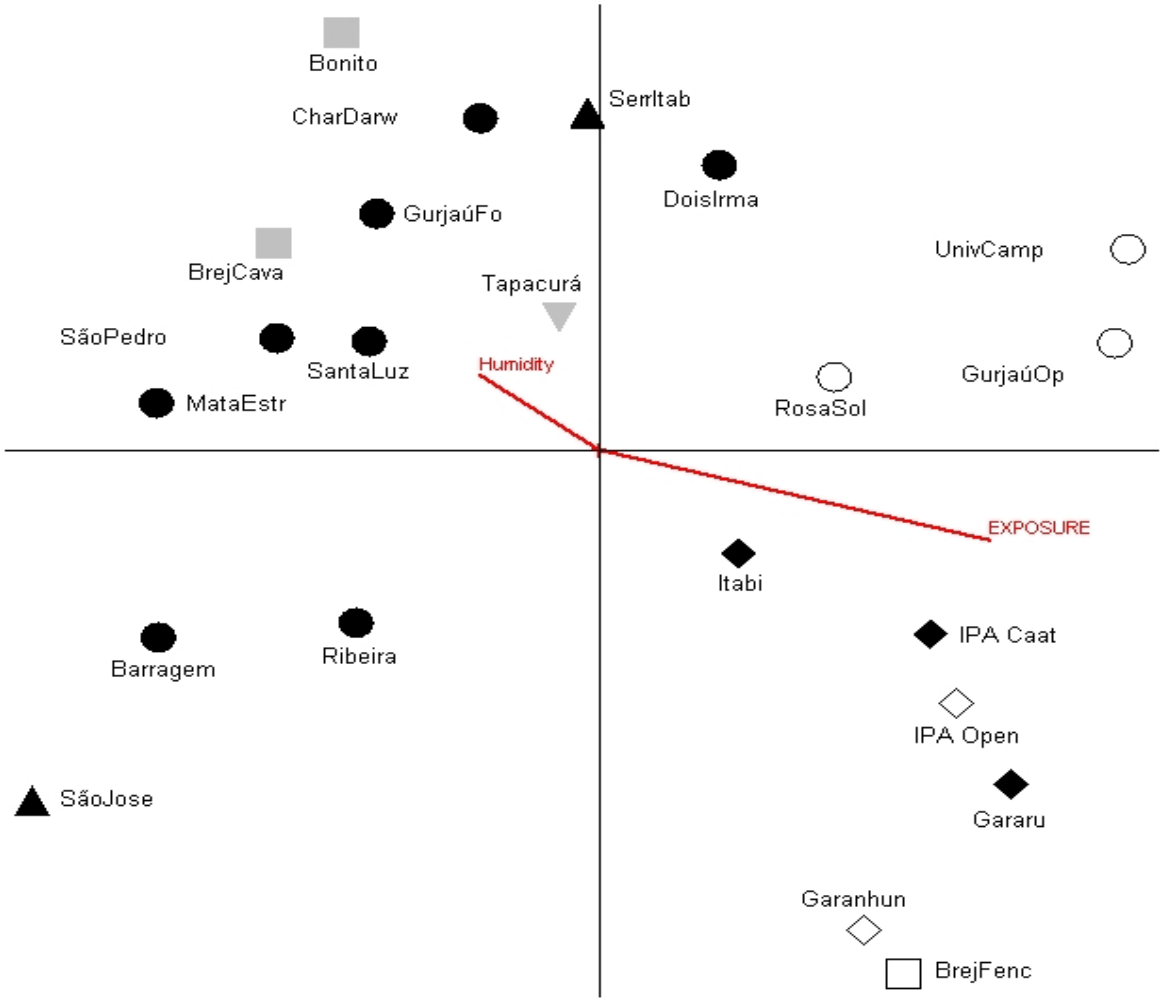

FIG. 4. NMS ordination of the 22 sites. Grey lines indicate correlations of the main axes with precipitation regime and exposure.

The cluster analysis of the 22 sites, based on their lichen species composition, chiefly confirms the pattern observed in the NMS diagram, with the formation of two major groups (Figure 5). Again, the first group comprises the sites representing understory rainforest vegetation, namely all Zona da Mata and Brejos de Altitude sites, while the second group corresponds to all the sites located within the Caatinga and the exposed Zona da Mata and Brejos de Altitude sites.

The first group can be divided into two subgroups. In the first subgroup there are three localities, Mata Estrela (Rio Grande do Norte), Santa Luzia (Sergipe), and Serra de Itabiana (Sergipe). These last two rainforest remnants, which are both in the state of

Sergipe, are also grouped together in another smaller subdivision. The second subgroup can also be further divided into two smaller units: one with three rainforest fragments from the Mata Atlântica region, and the second with the two Brejos de Altitude. In the second group, two subgroups can be observed: one comprises the exposed Zona da Mata sites plus the site situated in the Agreste region plus one Caatinga site (Itabi), while the second subgroup is formed by the Caatinga sites plus the exposed Caatinga and Brejos de Altitude sites.

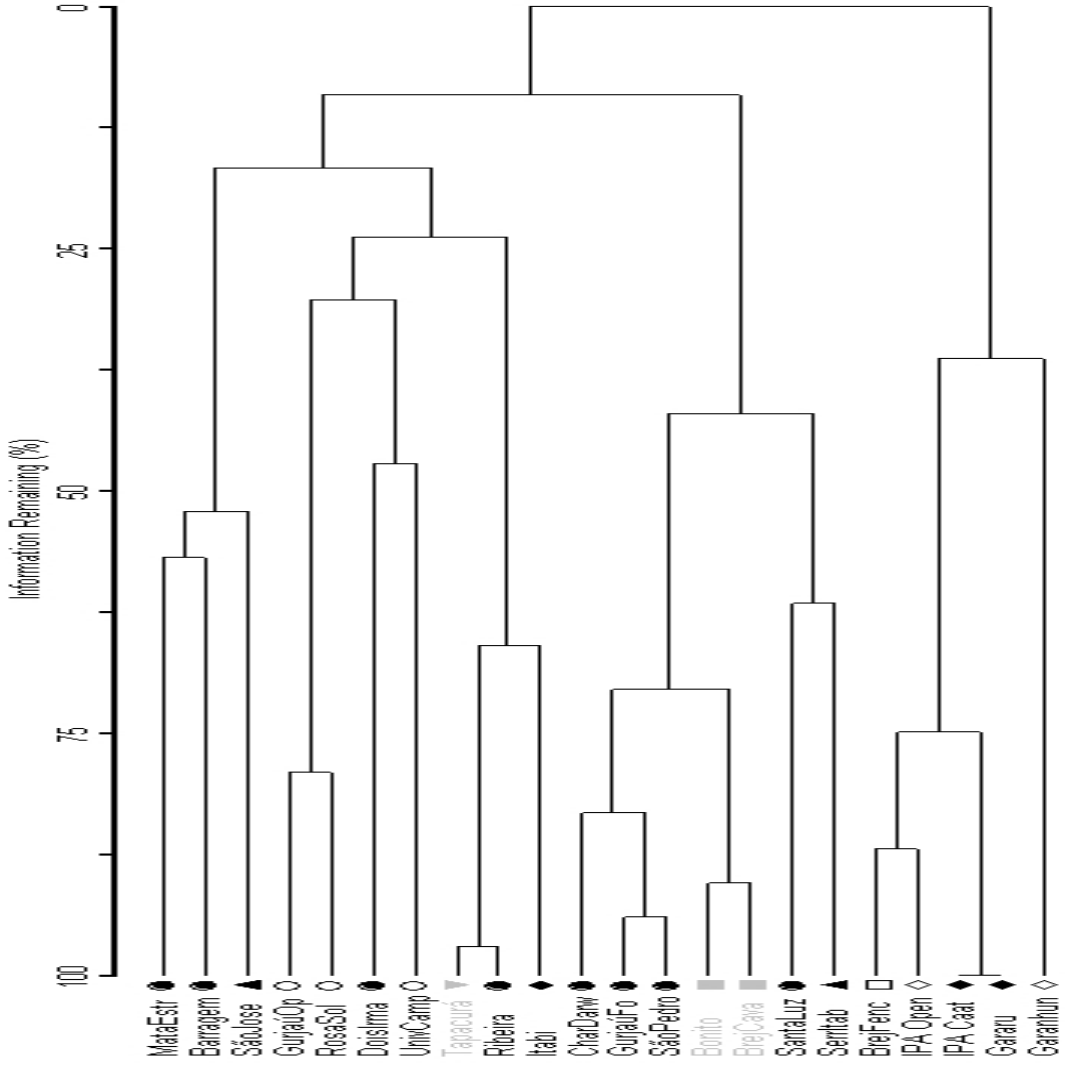

FIG. 5. Cluster analysis of the 22 sites.

Vegetation types and their indicator species

Among the 456 corticolous crustose and microfoliose lichen species found in the present study, only ten were shared among all three main vegetation types: *Dyplolabia afzelii*, *Lecanora helva*, *Malcolmiella fuscella*, *M. gyalectoides*, *M. leptoloma* and *M. vinosa*, *Phaeographis brasiliensis*, and *Trypethelium ochroleucum*, *T. subeluteriae*, and *T. tropicum*. Fifty-nine taxa were common between Zona da Mata and Brejos de altitude, 20 between Zona da Mata and Caatinga, and none between Brejos de Altitude and Caatinga, again suggesting an affinity of Brejos de Altitude with Zona da Mata rather than with Caatinga in terms of lichen species composition. A total of 366 species were unique to either Zona da Mata (245), Brejos de Altitude (67), and Caatinga (54), respectively (Fig. 5). Genera containing more than one species that are unique to the Zona da Mata or particularly well-represented there are *Arthonia*, *Arthothelium*, *Bactrospora*, *Bapalmuia*, *Bacidiopsora*, *Bathelium*, *Carbacanthographis*, *Coccocarpia*, *Cresponea*, *Crocynia*, *Cryptothecia*, *Enterographa*, *Fellhanera*, *Herpothallon*, *Letrouitia*, *Myriotrema*, *Opegrapha*, and *Sarcographa*. Unique to Brejos de Altitude or particularly well-represented there are *Astrothelium*, *Calopadia*, *Echinoplaca*, *Eugeniella*, *Hemithecium*, *Lopezaria*, *Sagenidium*, *Trichothelium*, and *Vainionora*. Genera restricted to Caatinga or most commonly found there include *Baculifera*, *Chrysothrix*, *Cratiria*, *Dirinaria*, *Hafellia*, *Lecanographa*, *Lecanora*, *Maronina*, *Ochrolechia*, *Pertusaria*, *Physcia*, *Pyxine*, *Rinodina*, and *Stigmatochroma*.

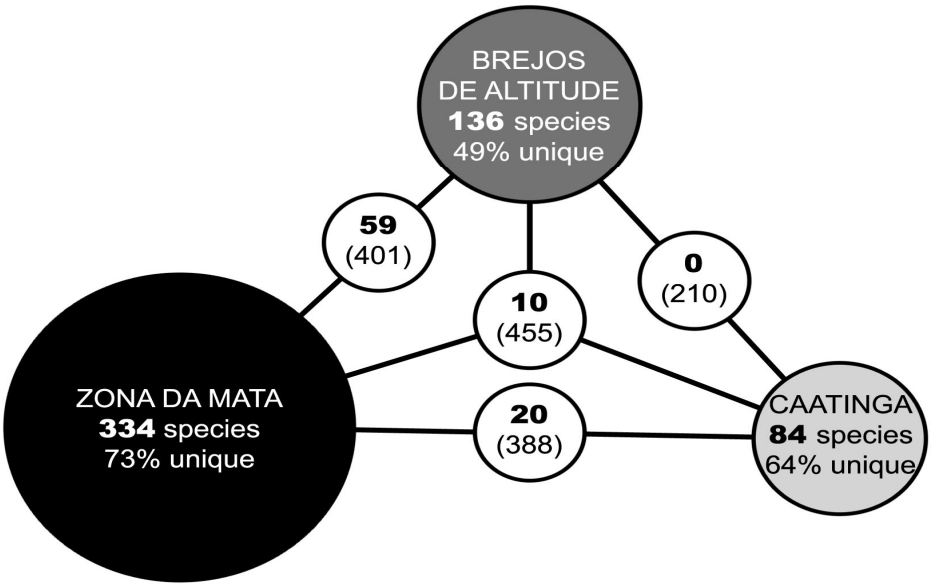

FIG. 6. Number of lichen species unique for and shared between each of the three main vegetation types. Numbers in boldface in white circles indicate number of shared species between vegetation types, and numbers in parentheses below indicate total number of species for combined vegetation types.

Although 245 lichen species are unique to the Zona da Mata, none is significantly indicative for this type of vegetation (Table 3). This is due to the fact that the Zona da Mata sites included in the study (15) outnumber the Brejos de Altitude (2) and Caatinga sites (5), so the deviations in the observed from the expected indicator values (IV) are too small to produce significant p-levels. For example, a species present at all 15 Zona da Mata sites but absent from Brejos de Altitude and Caatinga would have an expected frequency within the Zona da Mata of $15^2 / 22 = 10.2$ if randomly distributed, and the observed frequency of 15 would still be within the 95% confidence interval of that value. On the other hand, a species present at all five Caatinga sites would have an expected random Caatinga frequency of $5^2 / 22 = 1.14$; in that case, the observed frequency lies outside the 95% confidence interval and the difference becomes significant at the 5% level. Accordingly, the Brejos de Altitude sites have 24 significantly indicate species and the Caatinga sites have eight (Table 3). Overall, the aspect of typical Zona da Mata, Brejos de Altitude, and Caatinga species is very different from each other (Figs 7–9).

TABLE 3. Indicator lichen species analysis for the three main vegetation types in northeastern Brazil. Columns 2–4 give the combined abundance/frequency score for each species within each vegetation type; IV indicates observed and expected indicator values (combined abundance/frequency scores) for the vegetation type in which the species is relatively most common.

	Zona da Mata	Brejos	Caatinga	Obs. IV	Exp. IV	p-level
Zona da Mata						
Malcolmiella psychotrioides	53	0	0	53.3	30.7	0.100
Pyrenula mamillana	40	0	0	40.0	27.2	0.103
Malcolmiella badimioides	53	0	0	53.3	31.0	0.107
Letrouitia domingensis	40	0	0	40.0	28.1	0.127
Graphis glaucescens	33	0	0	33.3	26.6	0.250
Letrouitia vulpina	33	0	0	33.3	26.9	0.292
Pyrenula nitidula	33	0	0	33.3	27.1	0.299
Cryptothecia striata	27	0	0	26.7	23.8	0.417
Malcolmiella granifera	27	0	0	26.7	24.7	0.445

Coenogonium subdentatum	27	0	0	26.7	25.3	0.489
Arthonia bessalis	27	0	0	26.7	25.1	0.492
Phaeographis crispata	27	0	0	26.7	25.2	0.500
Brejos de Altitude						
Chapsa platycarpella	5	84	0	84.3	28.9	0.003
Herpothallon rubrocinctum	0	95	0	94.9	21.4	0.004
Byssoloma chlorinum	0	100	0	100	18.3	0.005
Byssoloma leucoblepharum	0	100	0	100	18.6	0.005
Byssoloma aff. meadii	0	96	0	95.7	21.1	0.005
Calopadia pruinosa	0	100	0	100	18.6	0.005
Diorygma reniforme	0	100	0	100	18.6	0.005
Echinoplaca leucotrichoides	0	100	0	100	18.6	0.005
Malcolmiella hypomela	0	100	0	100	18.5	0.005
Phaeographis kalii	0	100	0	100	18.3	0.005
Trichothelium horridulum	0	100	0	100	18.2	0.005
Coenogonium geralense	0	94	0	93.7	21.4	0.007
Chapsa dilatata	11	73	0	73.2	29.2	0.008
Malcolmiella gyalectoides	4	78	1	77.6	28.9	0.010
Malcolmiella leptoloma	2	82	1	82.2	27.9	0.010
Porina nucula	3	85	0	84.9	26.3	0.010
Malcolmiella atlantica	2	86	0	85.7	24	0.011
Coenogonium strigosum	6	76	0	76.3	28.4	0.019
Dyplolabia afzelii	8	71	1	70.6	30.6	0.023
Phaeographis haematites	10	71	0	71.4	28.4	0.027
Trypethelium tropicum	1	70	8	69.8	28.5	0.036
Laurera megasperma	0	47	0	46.9	17.8	0.049
Malcolmiella fuscella	0	48	0	47.9	17.4	0.049
Coenogonium pyrophthalmum	0	47	0	46.9	18.1	0.050
Caatinga						
Pyrrhospora coccinea	0	0	83	83.3	27.6	0.006
Baculifera pseudomicromera	0	0	67	66.7	24.8	0.022
Pertusaria flavens	0	0	50	50	22.4	0.024
Maronina multifera	0	0	50	50	21.8	0.024
Haematomma personii	0	0	67	66.7	25.1	0.026
Lecanora hypocrocina	0	0	50	50	22.1	0.026
Dirinaria leopoldii	1	0	43	43.1	24.5	0.051
Pertusaria quassiae	1	0	42	41.7	25.1	0.060

Among the lichen species unique to the Zona da Mata, there is a higher proportion of the subclasses *Arthoniomycetidae* (*Arthoniales*: *Arthoniaceae*, *Roccellaceae*) and *Chaetothyriomycetidae* (*Pyrenulales*: *Pyrenulaceae*), as well as of the families *Porinaceae* and *Thelotremataceae* (Table 4), compared to the overall proportions of these taxa among all lichen species. Because of the aforementioned explanation, this difference is not significant, however (Chi-Square test). The Brejos de Altitude have a significantly higher proportion of *Dothideomycetiae* (*Trypetheliaceae*) and *Ostropomycetidae* (*Ostropales*: *Gomphillaceae* and *Graphidadeae*), as well as *Pilocarpaceae* ($p < 0.05$).

Lecanoromycetidae (*Lecanorales*: *Lecanoraceae*; *Teloschistales*: *Physciaceae*) and the *Pertusariales* (*Pertusariaceae*) are the predominant subclasses, orders, and families found within the Caatinga sites ($p < 0.001$).

The predominant thallus type is squamulose for the Zona da Mata, byssoid for the Brejos de Altitude, and microfoliose for the Caatinga, but the observed differences are significant for the latter only (Table 4). Lichens in the Zona da Mata frequently have trentepohlioid photobionts ($p < 0.05$), while those in the Caatinga are associated with chlorococcoid photobionts ($p < 0.001$). Vegetative dispersal by isidia is more common within the Zona da Mata, while Caatinga lichens more frequently disperse by soredia, but the difference is not significant at the 5% level (Table 4). The predominant ascoma types are perithecia for the Zona da Mata, lirellae for the Brejos de Altitude, and apothecia and stromata for the Caatinga, but the patterns are not significant either. Ascospores are predominantly transversely septate and/or narrow in lichens of the Zona da Mata (not significant), thick-walled or muriform ($p < 0.05$) and hyaline in those of the Brejos de Altitude, and megalosporous, non-septate and/or brown (all $p < 0.05$) in Caatinga species. Both Zona da Mata and Brejos de Altitude have no predominant secondary substances, except for psoromic acid in the first, but Caatinga lichens show a highly significant predominance of atranorin, lichexanthone and other xanthones, as well as pulvinic acid derivates, as cortical substances, and norstictic acid as medullary substance.

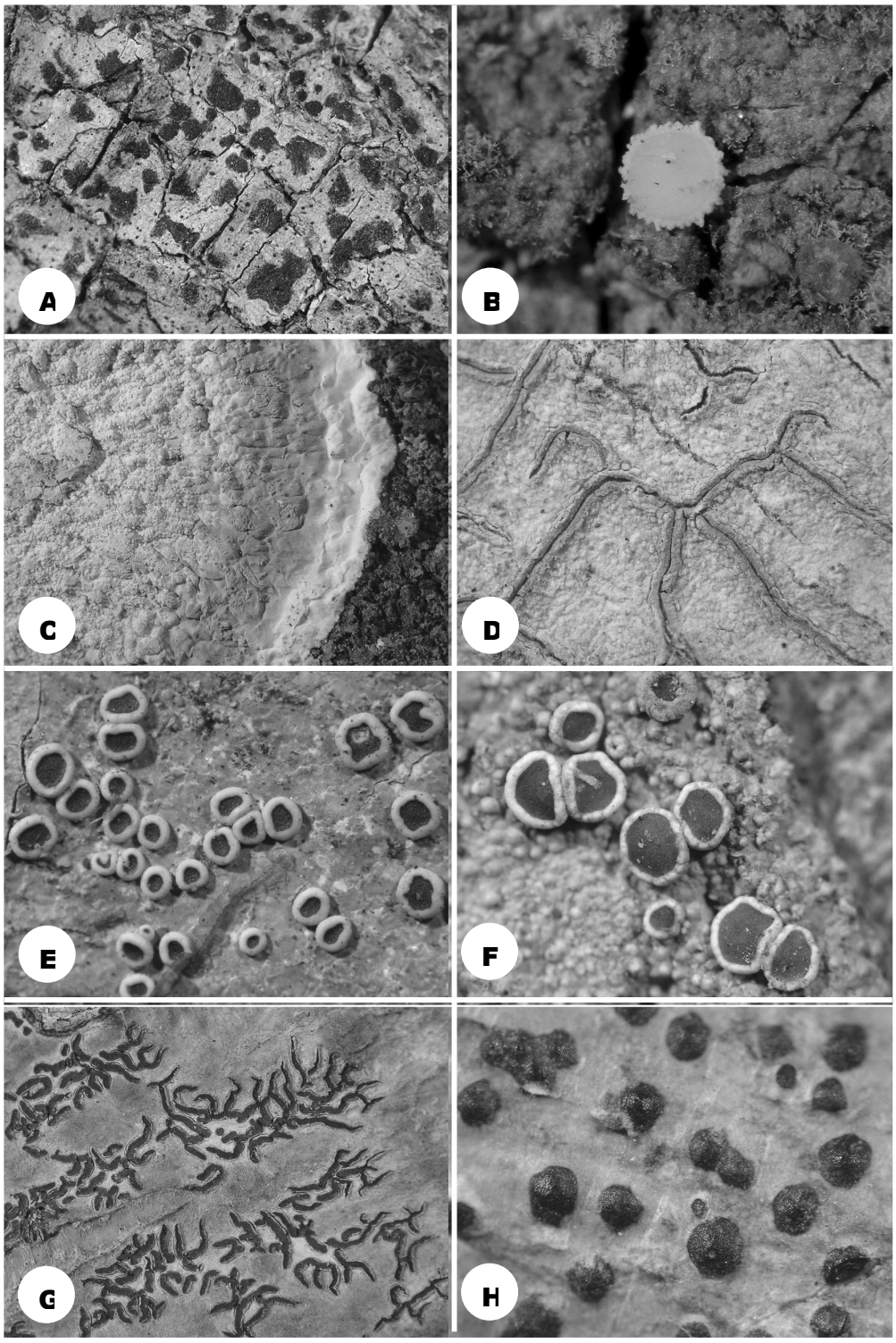

FIG. 7. Selected lichen species considered characteristic of the Mata Atlântica vegetation in NE Brazil: A. *Arhonia dictiospora*; B. *Coenogonium subdentatum*; C. *Cryptothecia striata* [00-504]; D. *Graphis glaucescens* [00-578]; E. *Letrouitia domingensis*; F. Malcolmiella badimioides [00-159]; G. *Phaeographis crispata* [00-865]; H. *Pyrenula nitidula* [00-254].

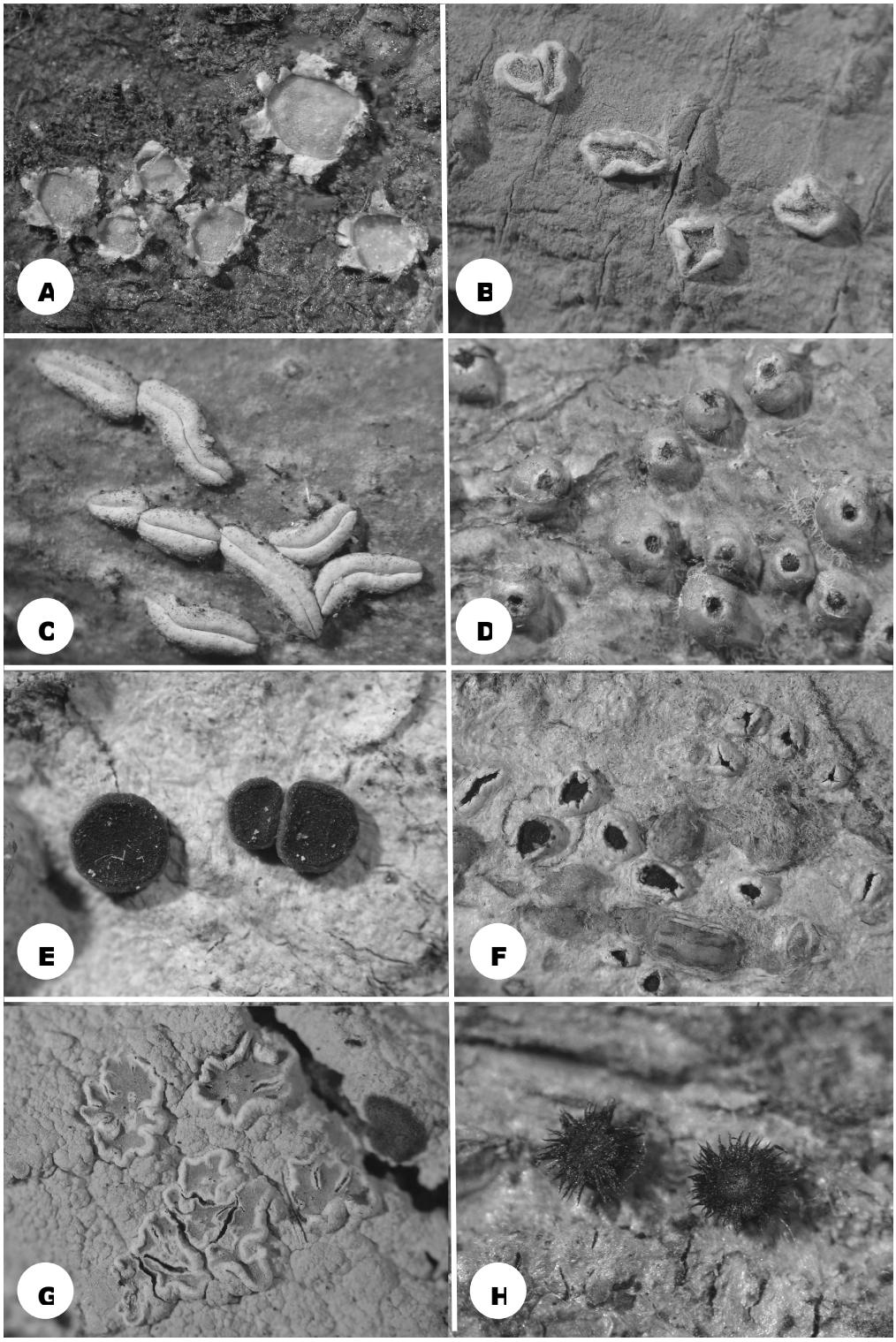

FIG. 8. Selected lichen species considered characteristic of the Brejos de Altitude vegetation in NE Brazil: A. *Chapsa platycarpellum* [00-328]; B. *Diorygma reniforme* [00-388]; C. *Diplolabia afzelii* [00-245]; D. Laurera megasperma; E. *Lopezaria versicolor* [00-569]; F. *Phaeographis kalbii* [00-639]; G. *Sagenidiopsis undulatum* [00-865]; H. *Trichothelium horridulum* [00-279].

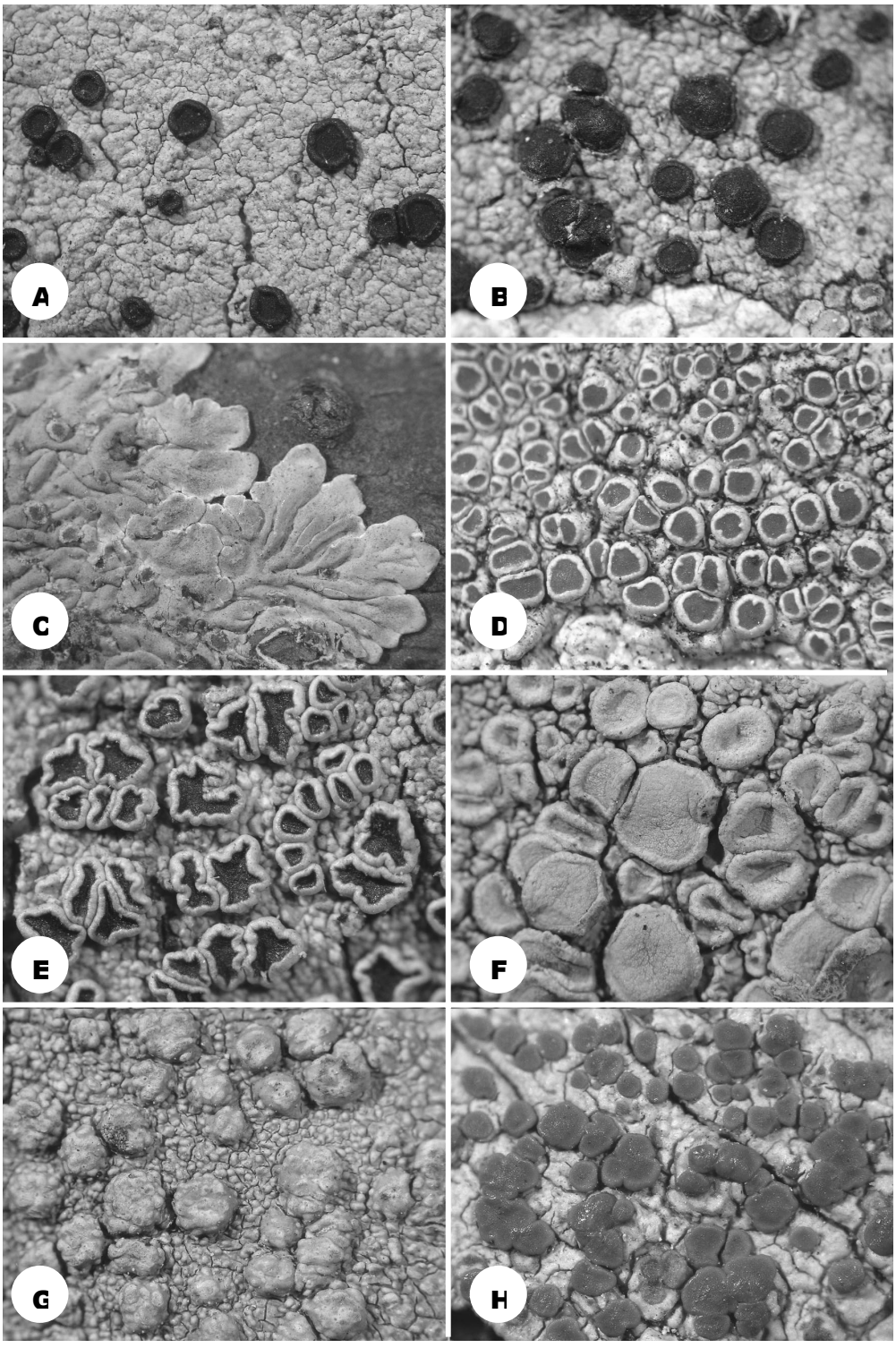

Fig. 9 Selected lichen species considered characteristic of the Caatinga vegetation in NE Brazil: A. *Baculifera pseudomicromera* [00-73]; B. *Cratiria lauricassaea* [01-84]; C. *Dirinaria leopoldii* [01-20]; D. *Haematomma persoonii* [2133]; E. *Maronina multifera* [00-659]; F. *Ochrolechia africana* [00-122]; G. *Pertusaria quassiae* [-27]; H. *Pyrrhospora coccinea* [00-120].

TABLE 4. Differences in the relative proportion of lichen species belonging to different higher taxa and showing different morphological, anatomical, and chemical features, between the three main vegetation types (Chi-Square test). Predominant taxa and features are indicated in bold face. TTT = highly significant ($p < 0.001$), T = significant ($p < 0.05$), (T) = tendential ($p < 0.1$), and (–) = not significant.

	Zona da Mata	p-level	Brejos de Altitude	p-level	Caatinga	p-level
Subclass	*Arthonio-mycetidae* *Chaetothyrio-mycetiae*	(–)	*Dothideo-mycetidae* *Ostropo-mycetidae*	T	***Lecanoro-mycetidae***	T
Order/Suborder	*Arthoniales* *Ostropales* *Pyrenulales*	(–)	*Ostropales*	T	*Lecanorales* ***Pertusariales*** ***Teloschistales***	TTT
Family	*Arthoniaceae* *Porinaceae* *Pyrenulaceae* *Roccellaceae* *Thelotremataceae*	(–)	***Gomphillaceae*** *Graphidaceae* ***Pilocarpaceae*** ***Trypetheliaceae***	T	***Lecanoraceae*** ***Pertusariaceae*** ***Physciaceae***	TTT
Thallus type	squamulose	(–)	byssoid	(–)	**microfoliose**	(T)
Photobiont	**trentepohlioid**	T	[none]	(–)	**chlorococcoid**	TTT
Ascoma type	perithecia	(–)	lirellae	(–)	apothecia **stromata**	(–)
Vegetative dispersal	isidia	(–)	[none]	(–)	**soredia**	(T)
Ascospore type	[none]	(–)	thick-walled	(–)	**megalosporous**	T
Ascospore septa	transverse	(–)	**muriform**	T	**non-septate**	T
Ascospore shape	narrow	(–)	broad	(–)	broad	(–)
Ascospore color	[none]	(–)	hyaline	(–)	**brown**	T
Chemistry	nil psoromic acid	(–)	**nil**	(–)	**atranorin** **lichexanthone** **norstictic acid** pulvinic acids xanthones	TTT

Discussion

As already stated in the introduction, few studies are available in which lichen diversity, especially microlichens, was assessed for tropical rainforest vegetation. Comparisons of the numbers found in this study with other sites in the tropics are therefore difficult. Analysis of other tropical localities yielded a large range of different numbers: thus, montane rain forest sites in Costa Rica, Colombia and Ecuador had 32–51 macrolichen and an undetermined number of microlichen species per site (Wolf 1993; Holz & Gradstein 2005; Noeske 2004), but in these cases, microlichens were left undetermined in the first two cited studies and determined mostly to genus level only in the last study. Also, the vegetation is quite different from the relatively drier and warmer northeastern Atlantic rainforest, and is generally expected to have higher lichen biomass but fewer species, especially microlichens. Lowland sites were investigated in Venezuela by Komposch & Hafellner (1999, 2000, 2002), in Guyana by Cornelissen & Ter Steege (1989) and in French Guiana by Montfoort & Ek (1990), and these workers reported 19-33 species of macrolichens per site but again left most of the microlichens unidentified. Microlichens were mostly determined to morphospecies level only, which suggests that the real species numbers are higher. Indeed, the study by Aptroot (1997, 2001) who identified 173 lichen species on a single tree in Papua New Guinea, and recent inventories in Costa Rica, with about 300 corticolous lichen species each found at a lowland and a lower montane rainforest site (Lizano *et al.*, in prep.; Moncada *et al.*, in prep.) indicate that microlichens contribute most of the species diversity below 1000m altitude in the tropics.

Based on these figures, the number of species per site in the Mata Atlântica and Brejos area appears relatively high compared to the other mentioned areas in Brazil (Aptroot 2002), Venezuela, and Ecuador, except Costa Rica. However, due to the relatively dry conditions in this area, it can be expected that there are less lichen species compared to other lowland areas, for example the Amazon rainforest or the southeastern Atlantic rainforest. Also, foliicolous lichens add significantly to the diversity of the northeastern Atlantic rainforest, and in previous studies, a number of up to 97 species of foliicolous lichens were found per site (Cáceres *et al.* 2000). As laid out in the last part

of the present study (Cáceres *et al*. 2007b), the kind of sampling technique also affects the established species numbers, and it can be concluded that the actual diversity per site is about two to three times as high, due to species usually not collected with opportunistic sampling.

It can also be stated that the variation on the number of species is more pronounced between the localities of Mata Atlântica, followed by the Caatinga vegetation areas and Brejos de Altitudes, with much less variation. This coincides with the fact that fragmentation is more pronounced in the Mata Atlântica region than for the Brejos, which have been naturally isolated during geological times, and that the reduction of primary Caatinga sites affects the lichen biota less than the perturbation of Mata Atlântica areas. Indeed, it can be assumed that the original lichen biota within the Mata Atlântica on one hand and the Caatinga on the other hand was rather homogeneous, and thus the observed differences (beta diversity) and strong variation in species number, especially within the Mata Atlântica, seems to be largely due to fragmentation effects, which reduce lichen diversity significantly and in a partially stochastic manner due to individual disturbance history. In fact, this higher level of dissimilarity found here among the Atlantic rainforest remnants is certainly a very suitable indication of the large disturbance due to deforestation, since the species number per site is also considerably low. It shows that, as an effect of the fragmentation, only the total species compositions of many different localities will be able to accurately represent the original lichen diversity of the whole study area.

Experience with other tropical areas shows that vegetation of drier and more open character is generally less affected in its lichen biota, which explains that the beta diversity values among Caatinga sites and their variation in species number is less than that observed for the Mata Atlantica. The Caatinga vegetation has been always subjected to harsh climate conditions, with much less humidity and more exposure than the tropical rainforest patches along the coast. Therefore, the relatively high perturbation of this biome will not affect this natural lichen biota habitat as much as in the Mata Atlântica remnants, where deforestation will cause a change on the climate and natural conditions for many lichen species with lower level of tolerance. Brejos de Altitudes has proven to be also less affected, since historically the region is more protected and naturally isolated. The Brejos de Altitude could be considered as part of

the so-called 'Pleistocene refugia', which are areas of tropical forest that became isolated due the higher altitudes, where species richness and composition were not disturbed by unfavorable climate conditions (Whitmore 1990), while the remaining and surrounding lowland forest shifted to more coastal areas or vanished entirely along the eras, returning or migrating back sometime later. Thus, this type of isolated vegetation shows a very interesting pattern, since the dissimilarity level with the Atlantic rainforest sites as a whole are much higher than expected.

NMS and cluster analysis shows that the localities group mainly according to exposure (light intensity levels) and not vegetation types itself. The NMS ordination shows a distinct distribution of sites along a humidity and exposure gradient. One group is composed by localities with higher humidity and evergreen forest, which means all the Mata Atlântica fragments and Brejos de Altitudes areas, while the other group is based on sites with drier conditions and higher exposure, comprising all the Caatinga localities and secondary and open vegetation. The same pattern is observed with the cluster analysis where the first level of the dendrogram is already composed by two big groups, the Atlantic rainforest sites together with the two Brejos, and the Caatinga localities with more open, secondary vegetation formations.

Although none of the taxa reported for the coastal Mata region are significantly indicative for that type of vegetation, because of the high number of sites compared to other vegetation types, some groups are considered as being very representative of this biome. For example, all the *Malcolmiella* species reported for the whole study area are found on the Mata Atlântica. Other exclusive Mata Atlântica genera and species include *Letroutia dominguensis*, *L. vulpina*, *Phaeographis crispatula*, *Pyrenula mamillana*, *P. nitidula*, among others. The Brejos de Altitude are characterized by a high number of indicative species, including *Lopezaria versicolor*, a typically montane crustose lichen. In the Caatinga, the following taxa were found to be significant indicator species: *Haematomma persoonii*, *Maronina multifera*, *Pyrrhospora russula*, and *Baculifera pseudmicromera*. The lichen species considered as typical for the Caatinga area are in part the same as found in more exposed vegetation (and the canopy) of Atlantic rainforest fragments. This is what would be expected since it was demonstrated above that species compositions of each vegetation type are rather grouping according to light levels. One striking exception is *Pyrrhospora*, where the canopy taxon of the Brejos de

Altitude is a different species (*P. coccinea*) as the one occurring in the Caatinga vegetation (*P. russula*).

Only ten of all the reported 456 taxa (ca. 2%) in the present study are shared between all three major vegetation types which means, on the other hand, that each vegetation type contributes significantly to the overall lichen diversity of northeastern Brazil. The low number could be explained by the differences between all the investigated vegetation types, which also have different paleogeographical history. The relatively low number of shared species between the Mata Atlântica and the Brejos de Altitude suggests that the latter had been isolated for quite some time. On the other hand, very few species are restricted to that type of vegetation on a global level; instead, the overall composition indicates a lichen biota typical of tropical montane rain forests of higher altitude. Thus, it is more likely that the so-called 'Massenerhebungseffekt' (mass elevation effect) is responsible for the observed differences, since it causes the isolated Brejos de Altitude to harbor lichen communities typical of much higher elevations and thus different from the lowland Mata Atlântica.

When considering the differences in the relative proportion of lichen species belonging to different higher taxa and showing different morphological, anatomical, and chemical features, between the three main vegetation types, it is noted that the taxa reported for Caatinga areas showed the most significant results. For example, in regard to the systematic position, the presence of the orders Lecanorales, Pertusariales, and Teloschistales and families Lecanoraceae, Pertusariaceae, and Physciaceae in Caatinga sites is highly significant ($p < 0.001$). This agrees with the fact that the chlorococcoid photobiont present in most of the lichen taxa for this very exposed vegetation is also highly significant ($p < 0.001$). On the other hand, the trentepohlioid photobiont showed only a tendency for the Zona da Mata ecossystem ($p < 0.1$) and no significant values were found for the Brejo de Altitudes concerning this character.

Ascospores types were also highly significant for the Caatinga taxa only, being the most characteristic the megalosporous, non-septate and/or brown ascospores (all with $p < 0.05$ values). This is a very good indication that the type of ascospores is well adapted to the harsh climatic conditions in Caatinga areas, where the exposition is intense, and the thick ascospores wall, the large size and brow color can be considered as a survival strategy. This thought can be also further extended to the presence or not of cortical and

medullary secondary substances. Except for psoromic acid in the Zona da Mata lichens, only the Caatinga characteristic species show a highly significant predominance of atranorin, lichexanthone and other xanthones, as well as pulvinic acid derivates, as cortical substances, and norstictic acid as medullary substance.

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CÁCERES, M. E. S., LÜCKING, R. & RAMBOLD, G. (2007b): **Phorophyte specificity and environmental parameters as determinants for species composition, richness and area cover in corticolous crustose lichen communities in the Atlantic rainforest of northeastern Brazil.**
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Phorophyte specificity and environmental parameters as determinants for species composition, richness and area cover in corticolous crustose lichen communities in the Atlantic rainforest of northeastern Brazil

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A transect of 47 mature trees was studied within an Atlantic rainforest plot in northeastern Brazil in order to determinate potential phorophyte specificity and the effects of environmental parameters, in particular bark characteristics, on the structure of corticolous, crustose microlichen communities, expressed by the parameters lichen species richness (alpha-diversity), area cover, and species composition. A total of 150 species was found, with most being rare to extremely rare (less than 10% steadiness). Multivariate analysis of sample plots, including non-metric multidimensional scaling (NMS), detrended correspondence analysis (DCA), and canonical correspondence analysis (CCA), and well as cluster analysis, indicated subtle patterns of phorophyte preferences among lichen species, corresponding to correlations with bark pH, degree of bark shedding, density and size of bark lenticels, and presence of milk sap. Individual and multiple regressions also revealed correlations between lichen species richness and area cover on one hand and bark pH (negative), density and size of bark lenticels (negative), degree of bark shedding (negative), presence of milk sap (positive), and diffuse site factor (positive). No distinct lichen communities were detected among the samples, but cluster analysis revealed three main sample groups and six subgroups with slightly different lichen species composition, each one with characteristic indicator species but with highly variable overall species composition. Beta-diversity, measured as relative Sørensen dissimilarity, was very high on average among samples and there was no spatial correlation of beta-diversity values, with spatially proximate samples varying the same way as spatially distant samples. However, beta-diversity was significantly lower among samples belonging to the same tree species, independent of their spatial arrangement. It is concluded that community formation in tropical rainforest understory lichens subtly correlated with two main environmental factors, phorophyte bark characteristics and microclimate, but is largely obscured by the stochastic effects of species dispersal, rare species, and individual historic events based on inter- and intraspecific interactions, but also the degree of phorophyte tree diversity. In particular, in ecosystems with high tree diversity, a low degree of phorophyte preference increases the probability of successful thallus establishment based on stochastic diaspore dispersal. It is predicted that phorophyte specificity is best observed in model systems with low tree and low lichen alpha-diversity, distinct differences between tree species in terms of bark characteristics, homogeneous population structure, and low microclimatic variation.

Lichens occur in practically all ecosystems, from hot and cold deserts to lush tropical rainforests, and even in aquatic and marine environments (HENSSEN & JAHNS 1974; SEAWARD 1977; HALE 1983; HAWKSWORTH & HILL 1984; KERSHAW 1985; KAPPEN 1988; NASH 1996; SEAWARD 2000; BRODO et al. 2001; APTROOT & SEAWARD 2003). Due to their symbiotic nature, lichens are partially independent of the substrate and receive most of their water and nutrients through the atmosphere. Therefore, lichens can grow on all kinds of substrata, including rock, soil, bark (corticolous lichens), bryophytes, and even leaves. Often, lichens also grow on man-made substrata such as

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concrete and even metal, glass, and plastic (BAILEY 1974; SIPMAN 1994; SCHROETER & SANCHO 1996; LÜCKING 1998; GRAY 1999; SANDERS 2001; UPRETI & DIXIT 2002).

Notwithstanding, ecological studies in temperate regions indicate that lichens show certain habitat preferences concerning the nature of the substrate (structure, pH, nutrient content), light intensity, and air humidity (BARKMANN 1958; ADAMS & RISSER 1971; BRODO 1973; JONES 1980; ESSEEN 1981; SCHMITT & SLACK 1990; WIRTH 1992; HAMADA et al. 1995; LOPPI & FRATI 2004; PECK et al. 2004). Similar habitat preferences would also be expected for tropical lichens, but because of the insufficient taxonomical knowledge especially of crustose microlichens, which make up much of the lichen diversity in tropical ecosystems, only few investigations of this kind exist (SIPMAN & HARRIS 1989; GALLOWAY 1991; GRADSTEIN 1992; GRADSTEIN et al. 1996; MERWIN & NADKARNI 2001; COPPINS & WOLSELEY 2002). A number of studies on tropical lichen ecology show similar patterns as found in temperate zones, although based mostly on different species and genera. CORNELISSEN & TER STEEGE (1989) in Guyana and MONTFOORT & EK (1990) in French Guiana found that epiphytic lichens and bryophytes showed slight phorophyte specificity but also a pronounced vertical zonation from the forest understory to the canopy.

The most detailed study on tropical epiphytic lichens and bryophytes to date was presented by WOLF (1993a–c, 1994, 1995). This author used multivariate ordination and classification methods to analyze a large data matrix from several hundred samples made in different forest types in Colombia and found significant patterns in altitudinal zonation, community formation, and correlations with certain substrate parameters such as bark type, bark pH, and substrate nutrient content. Other studies, partically with a different focus, were presented by STEVENS (1979) for eastern Australia, BIEDINGER & FISCHER (1996) for central Africa, WOLSELEY & AGUIRRE-HUDSON (1997) for Thailand, and more recently by NÖSKE (2004) and NÖSKE & SIPMAN (2004) for Ecuador and by HOLZ & GRADSTEIN (2005) for Costa Rica. ZOTZ (1999) and ZOTZ et al. (2003) attempted to explain the patterns of altitudinal zonation of tropical lichens by the ecophysiological characteristics of the different groups and growth types.

While these studies either largely neglected crustose microlichens or concentrated on habitats where these lichens are comparatively less abundant and diverse, MARCELLI (1992) was the first to investigate the lichen biota of tropical mangrove forests in southeastern Brazil, including many crustose taxa. He found that lichen species responded to microclimatic parameters (illumination and humidity) and showed a zonation from the margins to the inner parts of mangrove vegetation, but also correlated with tree bark characteristics, including salt content. More recently, KOMPOSCH & HAFELLNER (1999, 2000, 2002) presented a detailed study on the ecology of tropical lowland rainforest lichens, using the crane system at the Orinoco river in Venezuela to access the different forest zones and to compare rainforest with savanna lichen communities. A very interesting experiment was performed by NADKARNI (2000) in Costa Rican cloud forest. Canopy branches were stripped off their epiphyte cover to observe the recovery of the epiphyte mats. No re-growth was observed until after five years, and the first organisms to colonize the bare branches were crustose and foliose lichens, indicating that lichens play an important role in both primary and secondary succession of tropical epiphyte communities. Otherwise, the only group of crustose tropical microlichens with a well-established taxonomy are foliicolous lichens, where microclimate proved to be the most important factor determining community formation, while phorophyte preferences are absent or rather subtle (NOWAK & WINKLER 1975; BARILLAS et al. 1993; LÜCKING 1995, 1998a–b, 1999a–c). CÁCERES et al. (2000) studied the foliicolous lichen biota of Pernambuco in Brazil, comparing the three main vegetation types (Zona da Mata, Caatinga, Brejos de Altitudes) and assessing the impact of deforestation and land use change on foliicolous lichen biodiversity, community structure, and conservation.

Assessment of phorophyte specificity and environmental preferences of tropical lichens, in particular crustose microlichens, is important in terms of studying lichen diversity and rainforest conservation. A certain degree of phorophyte preferences implies that lichen diversity depends on phorophyte diversity, which is nowadays much endangered. As much as 95–98% of the total original area coverage of the Atlantic rainforest have been deforested in northeastern Brazil, and many tree species have locally disappeared (FIDEM 1987; RANTA et al. 1998; WHITMORE 1990; CARDOSO SILVA & TABARELLI 2000; MYERS et al. 2000). As a consequence, it can be assumed that a certain amount of lichen species and other organisms are also gone together with this immense number of phorophytes.

In the present study, phorophyte specificity and environmental preferences of corticolous microlichens were investigated in an Atlantic rainforest remnant in northeastern Brazil, in the state of Alagoas, along a transect including 47 trees belonging to 16 different species. Different phorophyte bark parameters, as well as relative light intensity (diffuse site factor), were measured to correlate lichen community parameters such as species composition, species richness, and relative area cover. Using morphological, anatomical, and chemical characters, all taxa were determined to species level, and multivariate methods were used to detect patterns of community formation and their dependence on phorophyte features and environmental parameters.

Material and methods

Study site

The study was carried out at RPPN Fazenda São Pedro (Reserva Particular de Patrimônio Natural), an Atlantic rainforest fragment in the municipality of Pilar, Alagoas state, in northeastern Brazil (Fig. 1). The reserve is a semi-private property, one of many areas chosen and partially financed by the Brazilian government, in order to prevent total deforestation by the owners.

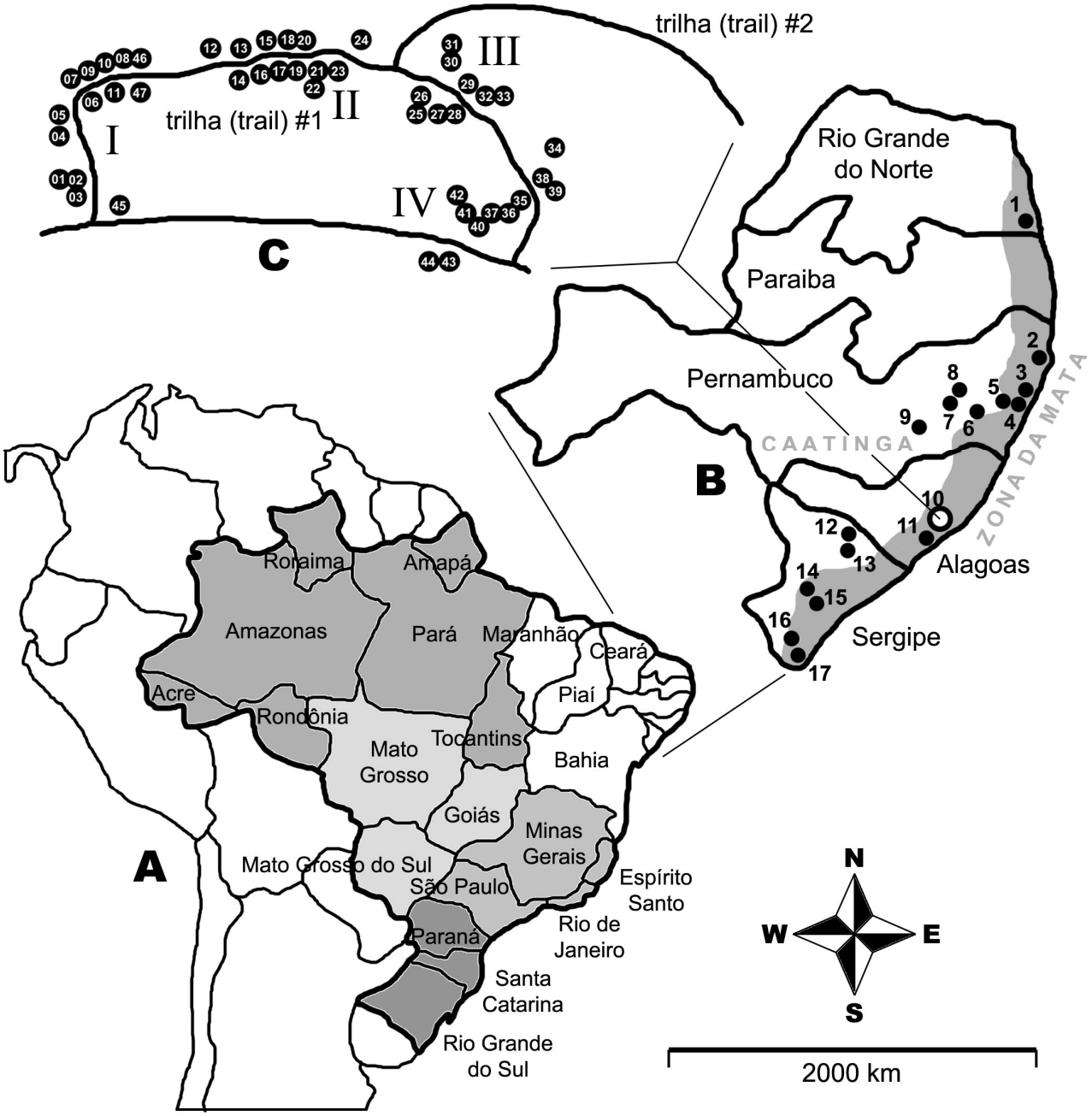

Fig. 1: Map of the study area showing location of the analyzed transect.

The rainforest patch inside of the RPPN Fazenda São Pedro covers about 50 ha of mostly undisturbed vegetation, together with some secondary formations bordering the forest. Some of the trees found in this remnant, which is a typical representative of the Atlantic rainforest vegetation, include *Apeiba tibourbou* Aubl. (Tiliaceae), *Artocarpus*

integrifolia L. (Moraceae), *Aspidosperma discolor* A. DC. (Apocynacea), *Bowdichia virgilioides* Kunth (Fabaceae), *Byrsonima basiloba* A. Juss. (Malpighiaceae), *Cupania racemosa* (Vell) Radlk. and *C. revoluta* Radlk. (Sapindaceae), *Dialium guianense* (Aubl.) Sandwith (Fabaceae), *Didymopanax morotoyoni* (Aubl.) Decne. & Planch. (Araliaceae), *Diplotropis purpurea* (Rich.) Amsh. (Fabaceae), *Jaracatia dodecaphylla* Vell. and *J. spinosa* (Aubl.) A. DC. (Caricaceae) and *Pachira aquatica* Aubl. (Bombacaceae).

Sampling

Collections were made along a transect on the main trail (trilha #1) of the rainforest remnant at RPPN Fazenda São Pedro. Phorophytes were selected within a range of 0–30 m on each side of the trail. A total of 47 phorophytes belonging to 16 different species were selected, with 1–3 trees each within a 10 × 60 m^2 area every 20 m along the transect and arranged in four major groups, with a distance of about 50 m between each group (Fig. 1). The phorophytes were identified to species or species groups with the assistance of a local guide and confirming identifications in the herbaria at IPA (Instituto Pernambucano de Pesquisa Agropecuária), PEUFR (Universidade Federal Rural de Pernambuco), and UFP (Universidade Federal de Pernambuco), all in Recife. Both scientific and local names were recorded (Table 1).

Tab. 1: Tree species used in the transect study, their local names, family assignment, and number of samples analyzed (excluding the three sample trees lacking lichens).

Tree species (species group)	Local name	Family	Samples
Artocarpus integrifolia L.	Jaqueira	Moraceae	5
Byrsonima crassifolia L.	Murici	Malpighiaceae	1
Cecropia pachystachia Trécul	Imbaúba	Cecropiaceae	5
Cupania revoluta Radlk.	Camboatã-de-rêgo	Sapindaceae	12
Dialium guianense (Aubl.) Sandwith	Jitaí	Fabaceae	3
Didymopanax morotoyoni (Aubl.) Decne. & Planch.	Sabacuim	Araliaceae	2
Diplotropis purpurea (Rich.) Amsh.	Sucupirá	Fabaceae	3
Goupia glabra Aubl.	Cupiúba	Goupiaceae	1
Guarea grandifolia DC.	Jitó	Meliaceae	2
Inga spp.	Ingazeira	Mimosaceae	2
Jacaratia dodecaphylla Vell.	Mamao jaracatiá	Caricaceae	3
Ochroma pyramidale L.	Jangada	Bombacaceae	2
Pachira aquatica Aubl.	Manguba	Malvaceae	1
Tabebuia spp.	Quirí de arco	Bignoniaceae	2
Thyrsodium spruceanum Benth.	Camboatã-de-leite	Anacardiaceae	1
Trattinnickia burseraefolia (Mart.) Willd.	Amescla	Burseraceae	1

A sample rectangle of 60 × 20 cm^2 was placed on each selected phorophyte, using transparent plastic sheets fixed to the tree trunk at breast level (center at 1.5 m height). Instead of using the same sample orientation for each tree, a line was laid around the tree at breast height and the number of different lichen morphospecies within adjacent 10 × 10 cm^2 presample quadrats was assessed. The center sample point of each tree was then laid on the center point of the presample quadrat with the highest lichen morphospecies, and the direction (angle) of that point against N (= 0º) was recorded as additional parameter. Three of the randomly selected trees did not have any lichen species present and were excluded from further study, which left 47 trees for the subsequent analyses.

For each sample rectangle, the outlines of the individual lichen thalli present within the rectangle were drawn on the transparent plastic sheet with black permanent marker, indication the area of each thallus. After drawing all specimens on the transparent sheet, the lichen thalli were collected and placed inside of labelled and numbered paper bags for further processing and identification in the laboratory. The lichen thalli drawn on the sample quadrats received the same collection numbers as the corresponding samples, using a code including the tree number and a consecutive number for each different lichen thallus (except for lichens that were recognized at species level already in the field and which received the same number throughout all samples).

Identification of the lichen material

Within each sample quadrat, all lichen thalli were identified to species level using morphological, anatomical, and chemical features. A detailed account of the identification procedures and consulted literature is given in CÁCERES (2007). The samples collected for this part of the work were also included on the species list for the general inventory, and voucher samples are deposited in B (Botanischer Garten and Botanisches Museum Berlin-Dahlem), F (The Field Museum, Chicago), and URM (Departamento de Micologia, Universidade Federal de Pernambuco, Brazil).

The total area for each species within each sample quadrat was determined by scanning the drawn sample sheets and analyzing them using the software package AutoCAD 2000; thallus area coverage was recorded in cm^2.

Determination of bark features and enviromnental parameters

The following nine parameters were determined for each phorophyte tree and sample: (1) circumference at breast height (as a relative estimate for tree age); (2) angle (orientation) of sample center point, using north as 0 and measuring clockwise between 0 and 360 degrees; (3) bark pH; (4) bark structure; (5) presence and size of bark lenticels; (6) degree of water repellence; (7) presence of milk sap; (8) degree of bark shedding; and (9) relative light intensity or diffuse site factor (ANDERSON 1964).

The pH level of the bark surface from the studied trees was measured using an ECOSCAN field pH-meter together with a flat head electrode (InLab® 426), as described by SCHMIDT et al. (2001) and KRICKE (2002). A silicone tube was inserted at the end of the flathead electrode in order to provide a small cavity between the bark and the electrode tip itself. This space was then filled with an approximately defined volume of liquid, i.e. the solvent solution, which was 0.2–0.3 ml 0.25 M KCl. For the measurements of the pH level, a small area of the bark surface of each studied phorophyte was selected, where no lichen or bryophyte growth could be observed. The flat head electrode was then placed on the surface of each bark area, and the defined amount of the solvent solution was applied inside of the electrode cavity (silicone tube) with a syringe. The pH-meter took about 3–4 minutes to complete the reading. Each time the syringe was used it was carefully washed with distilled water to prevent the interference with the other samples and also preserve the electrode.

Bark structure was assessed in four ordered categories (Fig. 2): 1 = completely smooth, 2 = uneven with substructures less than 1 cm in diam., 3 = uneven to sculptured with substructures 1–3 cm in diam., and 4 = coarsely sculptured with substructures more than 3 cm in diam. In addition, the presence and size of bark lenticels was recorded as follows: 1 = absent, 2 = sparse and/or small, 3 = abundant, 4 = large and conspicuous.

Water repellence was measured using a simple test with 10 repetitions on different bark pieces of each sampled tree. Bark samples were carefully dried for 5 hours using a mushroom air drier and droplets of identical size of distilled water were applied to the surface of each piece. The behaviour of the water drop was observed and the time measured until it was completely absorbed by the bark, if ever. Water repellence was measured in five categories: 1 = water absorbed quickly and completely within less than 5 seconds, 2 = water absorbed completely within 30 seconds, 3 = water absorbed within 1 minute, 4 = water absorbed extremely slowly, remaining as droplet more than 1 minute, 5 = water completely repellent and remaining as globose droplet on surface until evaporated. The presence of milk sap was recorded in binary fashion: 0 = absent, 1 = present. The degree of bark shedding was recorded in three categories: 0 = bark not shed, 1 = bark partly shed in small (up to 3 cm in diam.) pieces, 3 = bark regularly shed in large pieces (more than 3 cm in diam.).

Relative light intensity or diffuse site factor (ANDERSON 1964) was measured using hemispheric canopy photographs made at each sample point at a vertical angle of 90 degrees, using a NIKON F301 semi-automatic camera with a 180º fish-eye lens. The scanned black-and-white photographs were analyzed using the software Gap Light Analyzer (GLA) 2.0 (FRAZER et al. 2000), and the resulting values were categorized in five classes following LÜCKING (1997): 1 = 0–2% (shaded understory), 2 = 2–5% (transition towards light gaps), 3 = 5–13% (light gaps), 4 = 13–35% (transition towards canopy), 5 = 35–100% (exposed canopy).

Data analysis

The data were analysed using various ordination and classification methods (GREIG-SMITH 1978; GAUCH 1982; JONGMAN et al. 1995; MCCUNE & GRACE 2002), in order to detect data structure shared among different methods. Sample points were ordinated using two methods of indirect gradient analysis: non-metric multidimensional scaling (NMS) and detrended correspondence analysis (DCA). In addition, canonical correspondence analysis (CCA) was used as ordination method of direct gradient analysis, including species/sample score correlations with the measured environmental parameters in the calculation of two-dimensional sample scores. NMS is the only approach that does not make any assumptions on the data and is therefore the most robust methods regarding to data structure. DCA assumes one dominant underlying gradient and often fails to detect more than one gradient in the data. CCA has the same limitations, but in addition restricts data structure to the correlation with measured sample parameters, thus neglecting meaningful structure in the species abundance data that are not correlated to the sample parameters (MCCUNE & GRACE 2002). Comparison of NMS, DCA, and CCA was therefore used to detect possible conflict between analytical methods.

Cluster analysis was employed to assess hierarchical grouping of samples based on lichen species composition. Correlation of detected clusters with environmental and community parameters was assessed using non-parametric Kruskal-Wallis ANOVA and Mann-Witney U-test, as well as Spearman rank correlation. In addition, indicator species analysis was applied using a Monte-Carlo simulation to detect species that have significant preferences for certain tree species or sample groups apparent in the cluster analysis (MCCUNE & GRACE 2002). For that purpose, the grouping

variable was set to either tree species or sample cluster. The indicator species analysis then randomly shuffles the dominance and frequency data for each species using a Monte-Carlo simulation and through multiple repetition calculates an expected random distribution of the data among the predefined groups. The observed dominance and frequency values for each species are then compared to the expected values (based on the formation of a combined dominance / frequency indicator value IV), and are considered statistically significantly if they fall outside the 95% confidence intervall of the random distribution,

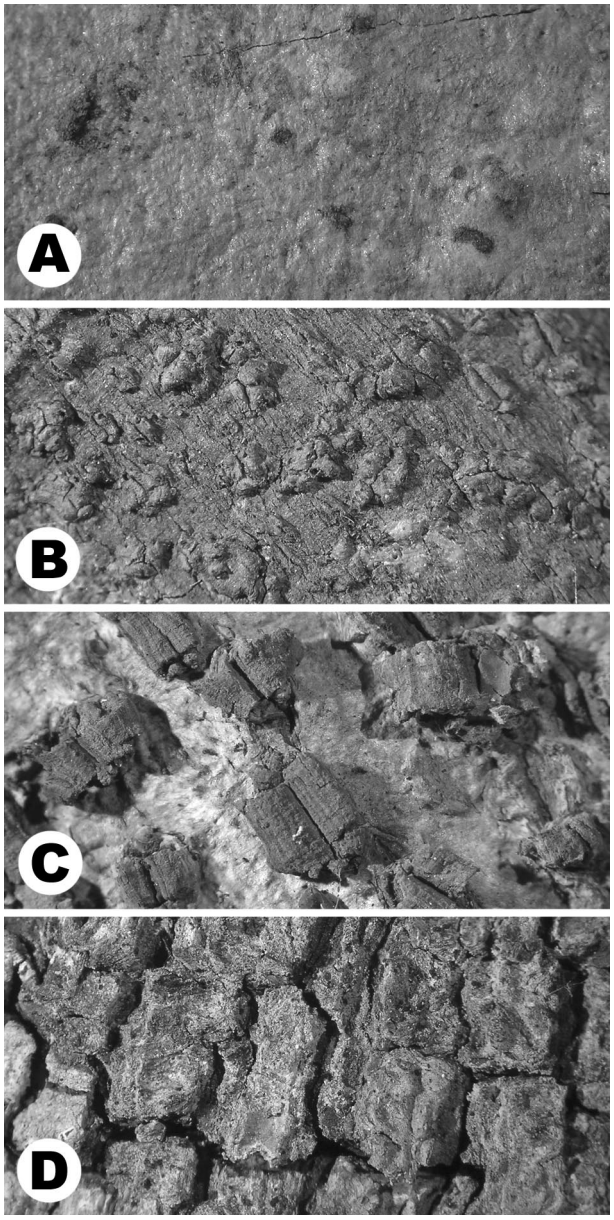

Fig. 2: Selected bark samples showing different types of bark structure and lenticells. A. *Dialium guianense*, smooth bark with shallow lenticells (1-2). B. *Trattinnickia burseraefolia*, rough bark with small, dense lenticells (2-3). C. *Cupania revoluta*, uneven bark with large lenticells (2-4). D. *Artocarpus integrifolia*, partly cracked bark lacking lenticells (3-1).

Settings for ordination and classification methods in PC-ORD were as follows: For NMS, the relative Sørensen index of dissimilarity was used. The analysis was run with 500 iterations per run and 999 runs in total, using 0.005 as stability criterion and 20 iterations to evaluate stability. In CCA, row and column scores were standardized by centering and normalizing. For all ordination methods, the number of axes was set to three. For cluster analysis, the relative Sørensen index of dissimilarity was used and flexible beta = –0.25 was applied as clustering algorithm. Flexible beta

produces clusters similar to those of Ward's method but in contrast to the latter is compatible with the Sørensen index (McCune & Mefford 1999; McCune & Grace 2002).

In order to filter noise that could obscure the underlying structure of the data, and to reduce the stochastic effects of rare species, two datasets were analyzed: complete data set with all tree samples (47) and all species (150), and partial data set including only tree species represented by at least two individuals (42 samples) and lichen species found on at least two trees among these (66 species).

The symmetrical matrix of relative Sørensen dissimilarity values resulting from the NMS and cluster analysis (same matrix) was subjected to spatial autocorrelation analysis and analysis of phorophyte dependence. The 47 sampled trees allowed for $47 \times 46 / 2 = 1081$ pairwise comparisons of the relative Sørensen dissimilarity index as a measure of beta-diversity among amples. Trees were arranged spatially in four groups I, II, III, and IV, according to their location within the transect (Fig. 1), and relative distances between trees were set to 0 when within the same group, to 1 when within adjacent groups (I vs. II, II vs. III, III vs. IV), to 2 when two groups away (I vs. III, II vs. IV), and to 3 when three groups away (I vs. IV). Kruskal-Wallis non-parametric ANOVA, Median test, and Spearman rank correlation were performed to test whether the four categorized relative distance groups (0, 1, 2, 3) differ in the distribution of pairwise beta-diversity among trees. A Mann-Whitney U-test was used to test whether beta-diversity differed among pairs of trees belonging to the same or to different species.

Individual correlation using Spearman rank correlation, as well as multiple regression were applied to assess relationships between lichen species richness and area cover and environmental parameters. The relationship of lichen species richness vs. area cover was explored using non-linear estimation techniques with least-squares regression.

Statistical analysis was performed using STATISTICA™ 6.0 and PC-ORD 4.0 (McCune & Mefford 1999).

Results

Species richness and area cover and frequency patterns

From 47 investigated phorophyte trees in this ecological study, a total of 150 lichen species was registered (Table 2). These represent 73% of all taxa found at the study site RPPN Fazenda São Pedro and 33% of all lichens found in the study area (northeastern Brazil) as a whole, which included 22 visited forest remnants on the states of Rio Grande do Norte, Pernambuco, Alagoas e Sergipe (Cáceres 2007; Cáceres et al. 2007a, b). About 50% of these taxa (76 species) were found exclusively within the transect, not being present in any other of the 16 collecting sites or outside the transect at the study site, and most of these are inconspicuous or cryptic taxa, which were not visualized on the field or were at first mistaken by other more common species (Cáceres et al. 2007b). As a whole, 205 species were found at the study site RPPN Fazenda São Pedro, only 21% of which (44 species) were shared between the transect and the sampled area outside the transect. The following genera are the most speciose within the transect: *Malcolmiella* (12 species), *Porina* (12), *Cryptothecia* (9), *Coenogonium* (8), *Herpothallon* (5), *Ocellularia* (5), *Opegrapha* (5), *Pyrenula* (5), *Bacidina* (4), *Fissurina* (4), *Myriotrema* (4), *Thelotrema* (4), *Anisomeridium* (3), *Arthonia* (3), *Enterographa* (3), *Letrouitia* (3), *Phaeographis* (3), and *Phyllopsora* (3). Most of these belong to the order Ostropales (seven genera), while Arthoniales and Lecanorales are represented by five and four species-rich genera, respectively. The total number of identified genera was 50, with the family Trypetheliaceae being remarkably underrepresented (Table 2). Two macrolichens of the genera *Canoparmelia* and *Parmotrema* were also found within the transect.

Tab. 2: Lichen species found within the studied transect at RPPN Fazenda São Pedro, in Alagoas, NE Brazil. Taxonomy and nomenclature follows Cáceres (2007).

Aciculopsora cinerea
Anisomeridium americanum
Anisomeridium polycarpum
Anisomeridium spec. (pycnidia)
Arthonia bessalis
Arthonia aff. *interveniens*
Arthonia spec.
Arthothelium aff. *chionectoides*
Astrothelium spec.
Astrothelium variolosum
Bacidina digitalis
Bacidina pallidocarnea
Bacidina varia
Bacidina aff. *varia*
Bapalmuia halleana
Enterographa aff. *byssoidea*
Fellhanera aff. *rhaphidophylli*
Fissurina dumastii
Fissurina incrustans
Fissurina instabilis
Fissurina radiata
Glyphis cicatricosa
Graphis furcata
Graphis glaucescens
Herpothallon spec. A
Herpothallon spec. B
Herpothallon spec. C
Herpothallon spec. E
Herpothallon spec. F
Lecanactis epileuca
Phyllopsora furfuracea
Phyllopsora longiuscula
Phyllopsora parvifolia
Plectocarpon syncesioides
Porina conspersa
Porina conspersoides
Porina curtula
Porina internigrans
Porina aff. *internigrans*
Porina limitata
Porina mastoidea
Porina nucula
Porina nuculastrum
Porina scabrida
Porina simulans

Bapalmuia lafayetteana
Byssoloma vanderystii
Canoparmelia crozalsiana
Chapsa alborosella
Chapsa dilatata
Chapsa punicea
Chiodecton malmei
Coccocarpia microphyllina
Coenogonium interplexum
Coenogonium linkii
Coenogonium luteocitrinum
Coenogonium nepalense
Coenogonium strigosum
Coenogonium subdentatum
Coenogonium subdilutum
Coenogonium subzonatum
Coniocarpon cinnabarinum
Crocynia gossypina
Crocynia pyxinoides
Cryptolechia nana
Cryptothecia effusa
Cryptothecia striata
Cryptothecia subcandida
Cryptothecia spec. A (sterile)
Cryptothecia spec. B (sterile)
Cryptothecia spec. C (sterile)
Cryptothecia spec. D (sterile)
Cryptothecia spec. E (sterile)
Cryptothecia spec. F (sterile)
Dichosporidium nigrocinctum
Diorygma poitaei
Dirinaria applanata
Dirinaria picta
Enterographa anguinella
Enterographa chiodectonoides
Letrouitia domingensis
Letrouitia subvulpina
Letrouitia vulpina
Lithothelium spec.
Malcolmiella albopiperina
Malcolmiella badimioides
Malcolmiella flavosorediata
Malcolmiella gyalectoides
Malcolmiella leptoloma
Malcolmiella pallidopiperis
Malcolmiella perisidiata
Malcolmiella piperis
Malcolmiella polycampia
Malcolmiella psychotrioides
Malcolmiella sorediata
Malcolmiella vinosa
Mazosia ocellata
Myriotrema congestum
Myriotrema costaricense
Myriotrema myrioporoides
Myriotrema spec.
Ocellularia bahianum
Ocellularia papillata
Ocellularia spec. C (sorediate)
Ocellularia spec. B (sorediate)
Opegrapha cf. *aperiens*
Opegrapha cf. *arengae*
Opegrapha atratula
Opegrapha aff. *contracta*
Opegrapha cf. *urosperma*
Parmotrema spec.
Pertusaria spec.
Phaeographis brasiliensis
Phaeographis haematites
Phaeographis scalpturata
Porina tetracerae
Pyrenula lineatostroma
Pyrenula macrocarpa
Pyrenula mamillana
Pyrenula nitidula
Pyrenula pyrenuloides
Pyrgillus javanicus
Ramonia intermedia
Sarcographa labyrinthica
Sclerophyton elegans
Sphinctrina tubiformis
Strigula phaea
Strigula stigmatella
Thelenella paraguayensis
Thelotrema glaucopallens
Thelotrema spec. A (sorediate)
Thelotrema spec. D (sorediate)
Tylophoron moderatum
[sterile] spec. (pustulose)
[sterile] spec. (pycnidia A)
[sterile] spec. (rusty)
[sterile] spec. (sorediate A)
[sterile] spec. (sorediate B)
[sterile] spec. (verrucose)
[unknown] spec. A
[unknown] spec. B
[unknown] spec. C
[unknown] spec. E
[unknown] spec. F
[unknown] spec. G
[unknown] spec. H
[unknown] spec. I
[unknown] spec. L
[unknown] spec. M
[unknown] spec. N

Taxa with high area cover are *Diorygma poitaei*, *Porina conspersa*, *Graphis glaucescens*, *Cryptothecia striata*, *Opegrapha* aff. *contracta*, *Porina* aff. *internigrans*, *Fissurina dumastii*, and *F. instabilis* (Table 3). However, only three species, *Diorygma poitaei*, *Porina conspersa*, and *Graphis glaucescens*, can be considered dominant, with 7.3 to 12.1% of total area cover. All other species have less than 5% cover relative to the total over all species, and most species have less than 1% (Table 3). With regard to frequency and steadiness, *Porina conspersa* is slightly more frequent than *Diorygma poitaei*, having been found within little more than 50% of the samples (Table 3). Together with *Graphis glaucescens*, which has lower frequency values, these can be considered the most dominant and steady species among all the lichens found in the study, since all other species either have low area cover relative to the total (less than 5%) or low steadiness (less than 10%).

Tab. 3: Lichens with the highest area cover [cm^2 over all samples] and frecuency [number of samples where species was present].

Species	Area cover [cm^2] (relative to total)	Species	Frequency [no. of samples] (Steadiness)
Diorygma poitaei	2368 (12.1%)	*Porina conspersa*	24 (51%)
Porina conspersa	1900 (9.7%)	*Diorygma poitaei*	20 (43%)
Graphis glaucescens	1415 (7.3%)	*Opegrapha* aff. *contracta*	16 (34%)
[unknown] spec. A	940 (4.8%)	*Dichosporidium nigrocinctum*	13 (28%)
Cryptothecia striata	732 (3.8%)	*Cryptothecia striata*	12 (26%)
Opegrapha aff. *contracta*	618 (3.2%)	[unknown] spec. E	11 (23%)
Porina aff. *internigrans*	589 (3.0%)	*Graphis glaucescens*	11 (23%)
Fissurina dumastii	588 (3.0%)	*Malcolmiella piperis*	11 (23%)
[sterile] spec. (rusty)	516 (2.6%)	*Fissurina dumastii*	9 (19%)
Fissurina instabilis	448 (2.3%)	*Cryptothecia* spec. E (sterile)	7 (15%)
Thelotrema spec. A	419 (2.1%)	[sterile] spec. (sorediate A)	6 (13%)
Letrouitia domingensis	410 (2.1%)	*Cryptothecia* spec. D (sterile)	6 (13%)
Plectocarpon syncesioides	375 (1.9%)	*Letrouitia domingensis*	6 (13%)
Dichosporidium nigrocinctum	347 (1.8%)	*Malcolmiella sorediata*	6 (13%)

Myriotrema costaricense	347	(1.8%)	*Myriotrema costaricense*	6	(13%)
Ocellularia papillata	339	(1.8%)	*Pyrenula mamillana*	6	(13%)
Cryptothecia spec. D (sterile)	301	(1.5%)	*Thelotrema* spec. A	6	(13%)
Arthonia aff. *interveniens*	297	(1.5%)	*Cryptothecia effusa*	5	(11%)
Cryptothecia effusa	287	(1.5%)	*Fissurina instabilis*	5	(11%)
Malcolmiella piperis	256	(1.3%)	*Malcolmiella flavosorediata*	5	(11%)
Opegrapha cf. *arengae*	256	(1.3%)	*Porina mastoidea*	5	(11%)
Cryptothecia spec. B (sterile)	244	(1.3%)	*Dirinaria picta*	4	(9%)
Bacidina digitalis	237	(1.2%)	*Fissurina radiata*	4	(9%)
Cryptothecia spec. E (sterile)	217	(1.1%)	*Mazosia ocellata*	4	(9%)
Canoparmelia crozalsiana	216	(1.1%)	*Pertusaria* spec.	4	(9%)
Pyrenula mamillana	213	(1.1%)	*Porina internigrans*	4	(9%)
[sterile] spec. (pycnidia A)	210	(1.1%)	*Pyrenula nitidula*	4	(9%)
Herpothallon spec. B	208	(1.1%)	*Sarcographa labyrinthica*	4	(9%)
Myriotrema myrioporoides	191	(1.0%)	*Strigula stigmatella*	4	(9%)
Lecanactis epileuca	177	(0.9%)	*Arthonia bessalis*	3	(6%)
Malcolmiella leucopiperis	175	(0.9%)	*Arthothelium* aff. *chiodectoides*	3	(6%)
Herpothallon spec. F	155	(0.8%)	*Chiodecton malmei*	3	(6%)
Ocellularia spec. A	153	(0.8%)	*Herpothallon* spec. F	3	(6%)
Anisomeridium spec.	145	(0.7%)	*Cryptothecia* spec. B (sterile)	3	(6%)
Malcolmiella polycampia	134	(0.7%)	*Cryptothecia subcandida*	3	(6%)
Arthothelium aff. *chiodectoides*	131	(0.7%)	*Malcolmiella albopiperina*	3	(6%)
Porina mastoidea	130	(0.7%)	*Malcolmiella polycampia*	3	(6%)
Phaeographis haematites	129	(0.7%)	*Ocellularia* spec. A	3	(6%)
Malcolmiella sorediata	121	(0.6%)	*Ocellularia* spec. B	3	(6%)
Sarcographa labyrinthica	111	(0.6%)	*Ocellularia papillata*	3	(6%)
Thelotrema glaucopallens	103	(0.5%)	*Phyllopsora parvifolia*	3	(6%)
Porina tetracerae	100	(0.5%)	*Porina nucula*	3	(6%)
Astrothelium variolosum	96	(0.5%)	*Porina tetracerae*	3	(6%)
[unknown] spec. H	90	(0.5%)	[unknown] spec. N	2	(4%)
Pyrgillus javanicus	84	(0.4%)	*Bapalmuia lafayetteana*	2	(4%)
Letrouitia subvulpina	80	(0.4%)	*Byssoloma vanderystii*	2	(4%)
Herpothallon "lanuginosum"	77	(0.4%)	*Canoparmelia crozalsiana*	2	(4%)
[sterile] spec. (pustulose)	76	(0.4%)	*Coenogonium linkii*	2	(4%)
Ocellularia bahiana	76	(0.4%)	*Herpothallon* "nigromarginatum"	2	(4%)
Bapalmuia lafayetteana	66	(0.3%)	*Cryptothecia* spec. A (sterile)	2	(4%)

With respect to area cover versus frequency ratio, two inverse strategies can be observed: species with high area cover but low frequency, and species with low area coverage but high frequency. Among the first group are *Porina* aff. *internigrans*, *Plectocarpon syncesioides*, *Arthonia* aff. *interveniens*, *Bacidina digitalis*, *Myriotrema myriotremoides*, and *Anisomeridium* spec., which all were found in one sample only but with very high area coverage (Table 4). Perhaps the most striking case is *Plectocarpon syncesioides*, a species new to science and the first genuinely lichenized representative of the genus (CÁCERES 2007), covering large areas of a single tree but not found elsewhere within the study site. On the other hand, species with low area cover but medium to high frequency (at least found in five samples) include *Malcolmiella flavosorediata*, *M. sorediata*, *M. piperis*, *Porina mastoidea*, *Dichosporidium nigrocinctum*, and *Pyrenula mamillana*. Among these, *Dichosporidium nigrocinctum* is the species with the highest frequency but always produces comparatively small thalli.

Tab. 4: Lichens with highest area cover / frequency ratios (145–940) and low overall frequency (ocurring in one sample only) compared to lichens with low area cover / frequency ratios (4.3–38.6) and medium to high overall frequency (ocurring in 5–16 samples).

Species	Frequency	Ratio	Species	Frequency	Ratio
[unknown] spec. A	1	940	[unknown] spec. E	11	4.3
Porina aff. *internigrans*	1	589	[sterile] spec. (sorediate A)	6	8.5
[sterile] spec. (rusty)	1	516	*Malcolmiella flavosorediata*	5	10.2
Plectocarpon syncesioides	1	375	*Malcolmiella sorediata*	6	20.2
Arthonia aff. *interveniens*	1	297	*Malcolmiella piperis*	11	23.3
Bacidina digitalis	1	237	*Porina mastoidea*	5	26.0
[sterile] spec. (pycnidia A)	1	210	*Dichosporidium nigrocinctum*	13	26.7
Herpothallon spec. A	1	208	*Cryptothecia* spec. E (sterile)	7	31.0
Myriotrema myrioporoides	1	191	*Pyrenula mamillana*	6	35.5
Anisomeridium spec.	1	145	*Opegrapha* aff. *contracta*	16	38.6

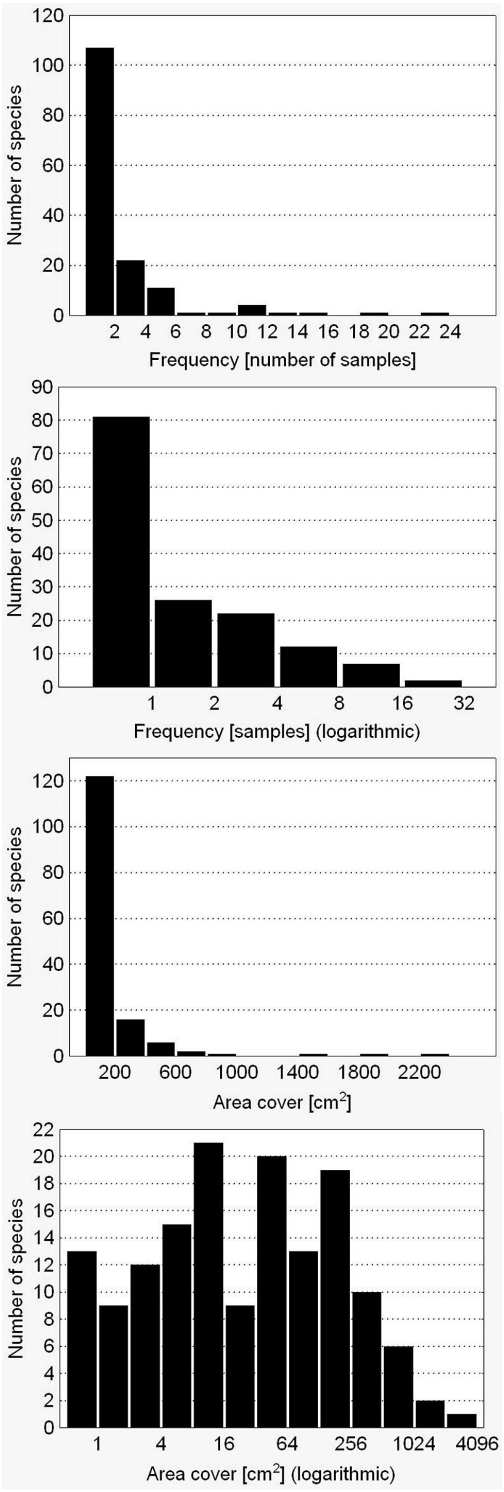

Fig. 3: Frequency (A–B) and area cover (C–D) distributions across lichen species based on linear (A, C) and logarithmic (B, D) scale, showing the predominance of rare to very rare species and the approximate log-normal shape of the logarithmically scaled area cover data (D). Logarithmic scaling does not create a log-normal shape for frequency values (B).

More than half (81) of the lichen species found within the transect occurred in a single sample quadrat (out of 47) only and are extremely rare (Fig. 3). Only one species, *Porina conspersa*, was found in at least half of the samples (24

or 51% steadiness) and thus may be considered common. Another four species occurred in at least one quarter of the samples, while 24% were found in three to four samples and another 26% in two samples only (steadiness less than 10%). Lichen species richness within the transect is thus clearly dominated by a large number of rare (2–4 samples) to extremely rare (1 sample) species, making up almost 90% of all the taxa. For that reason, the frequency distributions based on frequency and area cover are distorted towards the lower end, although the distribution based on logarithmically scaled area cover values still shows the log-normal shape typically found in natural plant and cryptogam communities, while such a shape is not observed in the logarithmically scaled frequency distribution (Fig. 3).

The number of lichen species per sample (alpha-diversity) varied between 1 and 24 (Fig. 4). The highest number of lichen species found on one single tree individual was 24, but this was the case for only one phorophyte. Most samples (23, i.e. almost 50%) had between eight and 12 species. Six samples had more than 12 species, and 18 samples had less. Average number of species per sample was 8.6. Lichen relative area cover per sample varied between 3% and 83% (Fig. 4). Most samples (26, i.e. more than half) had between 20% and 50% relative area cover. Eleven samples showed more that 50% relative area cover, while ten samples had less than 20%. Average relative area cover was 35%.

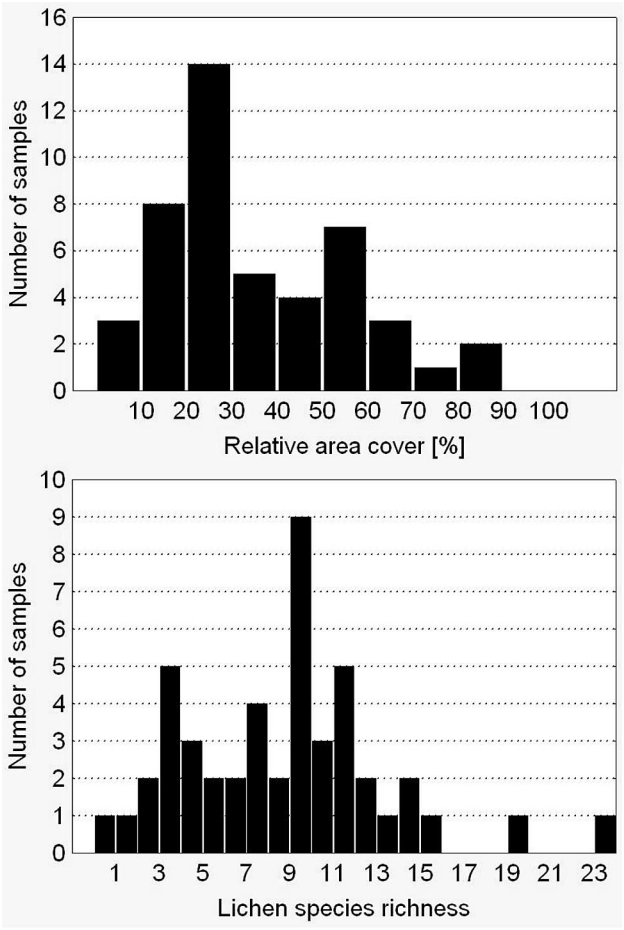

Fig. 4: Relative area cover and species richness (alpha-diversity) distributions across samples. Relative area cover is the percentage cover per sample (0–100%).

Ordination and classification of samples

NMS of the complete data set shows a subtle pattern of samples clustering according to tree species, correlating with the measured parameters of bark pH, lenticells, and bark shedding on the first axis (Fig. 5). No other correlations of the principal axes with environmental parameters are apparent. The 12 *Cupania* samples are mostly found in the left side of the diagram, correlating with increasing density and size of lenticells and increasing bark pH. The five *Artocarpus* species form two groups close to the second axis, with little correlation on the first axis but separated on the second axis uncorrelated with any of the measured parameters. The six *Cecropia* trees are mostly grouped in the left upper part of the diagram, while the three *Diplotropis* samples are found in the upper right quadrant and the three *Jacaratia*

samples in the lower half close to the second axis. Also the two samples each of *Dialium*, *Guarea*, *Inga*, and *Tabebuia*, appear close together, while those of *Didymopanax* and *Ochroma*, as well as the third *Dialium* sample, are more apart from each other.

DCA of the complete data set shows a slightly different pattern with respect to certain tree species (Fig. 6). The *Cupania* and *Cecropia* samples are here dispersed along the second axis, while those of *Artocarpus* are grouped near the origin. The *Dialium*, *Jacaratia* and *Ochroma* samples are closer together compared to NMS, while those of *Diplotropis* and *Tabebuia* are further apart. The first axis correlates with tree diameter and the degree of bark shedding, while no correlation with measured environmental parameters is apparent on the second axis.

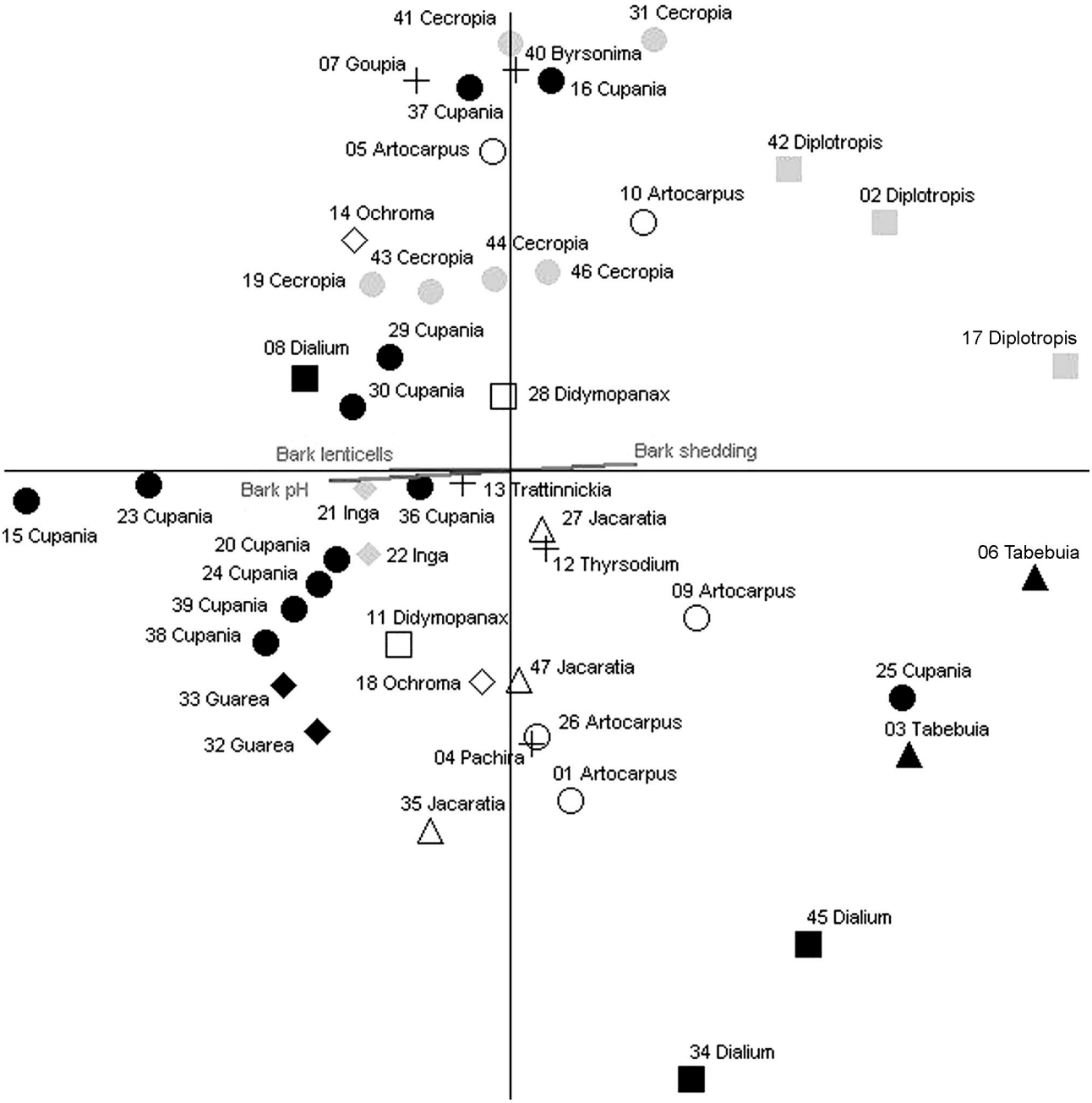

Fig. 5: Non-metric multidimensional scaling (NMS) plot of studied samples. Grey lines indicate correlations of principal axes with bark pH, bark lenticells, and bark shedding, derived independently through linear correlation of axes with all measured parameters.

Direct gradient analysis of the partial data set by means of CCA shows more distinct groupings according to tree species compared to the indirect gradient methods (Fig. 7). This suggests that the measured environmental parameters do explain part of the variation in species abundances, since CCA includes a step of linear correlation between species abundance scores and environmental parameters in the iteration process. In particular, the *Cupania* samples form a tighter group, partially correlated with high bark pH, while the *Artocarpus* samples separate along the second axis with high lichen area cover. The same is true for the *Inga* versus the *Cecropia* samples. On the first axis, the *Dialium*, *Diplotropis* and *Tabebuia* samples are polarized against *Cecropia* by a high degree of bark shedding and more pronounced bark structure, and against *Didymopanax*, *Inga* and *Ochroma* by lower bark pH. This effect is less pronounced for the *Guarea* and the *Jacaratia* samples.

The cluster analyses of all 47 sampled trees shows the formation of three main groups A, B, and C, with two subgroups each of three or more samples per cluster, A1 to B2 (Fig. 8). In contrast to the ordination methods (which retain the position of samples relative to each other), no major pattern of samples clustering according to tree species is evident, but small clusters of *Cecropia*, *Cupania*, *Dialium*, *Diplotropis* and *Tabebuia*, *Guarea*, *Inga*, and *Jacaratia* trees can be observed. There are also differences in environmental and community parameters between the main groups (Fig. 9). Group C includes samples with significantly higher bark pH than groups A and C (Kruskal-Wallis ANOVA: $p < 0.05$), while group B unites samples with significantly lower density and size of lenticells ($p < 0.05$). Groups B and C also show higher lichen species richness per sample (not significant), while group B has significantly higher lichen area cover per sample ($p < 0.05$). Differences in environmental parameters between subgroups (Fig. 9) are found within group A, with trees in subgroup A1 tending to have higher bark pH than those in subgroup A2 (Mann-Whitney U-test: not significant), and in group B, with trees of subgroup B1 having more pronounced bark structure ($p < 0.05$), absence of milk sap ($p < 0.05$), and lower species richness ($p < 0.05$) than those of subgroup B2.

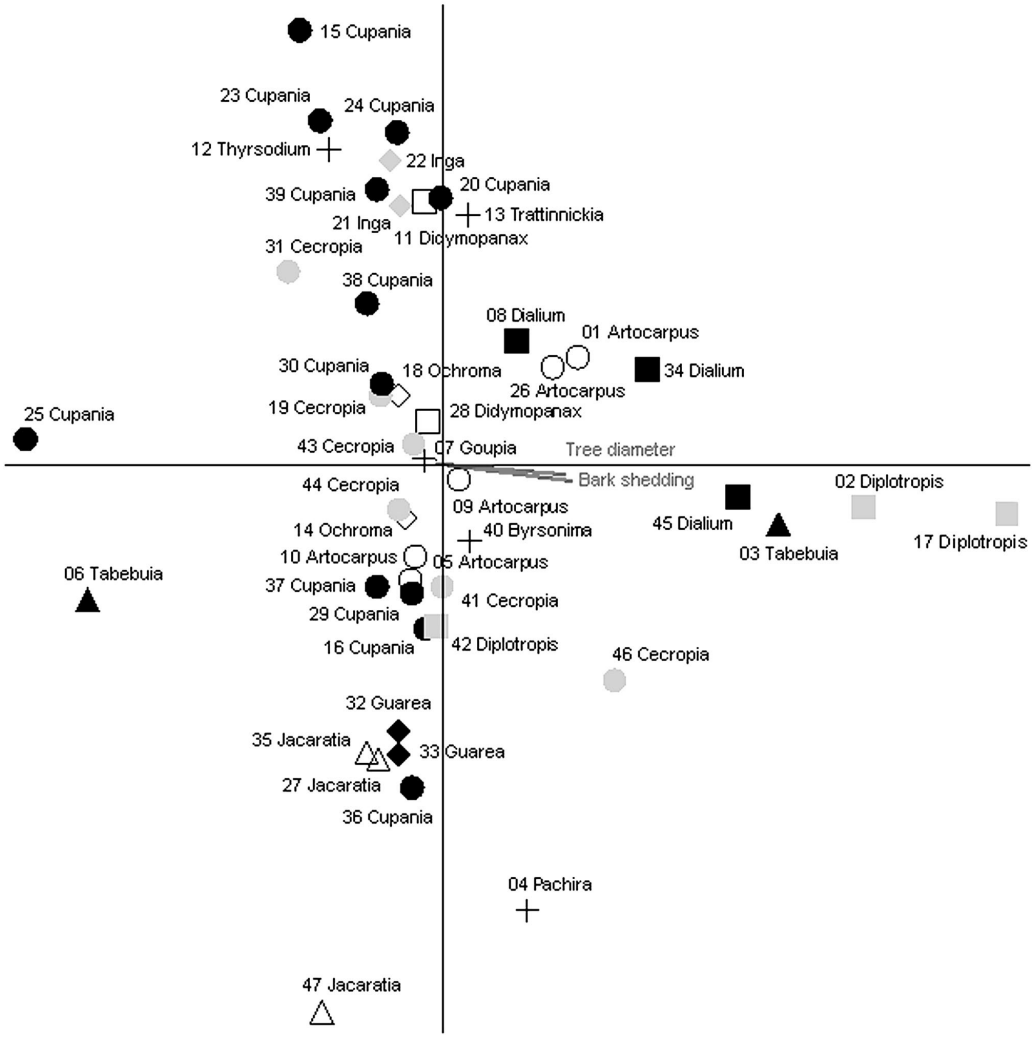

Fig. 6: Detrended correspondence analysis (DCA) plot of studied samples. Grey lines indicate correlations of principal axes with tree diameter and bark shedding, derived independently through linear correlation of axes with all measured parameters.

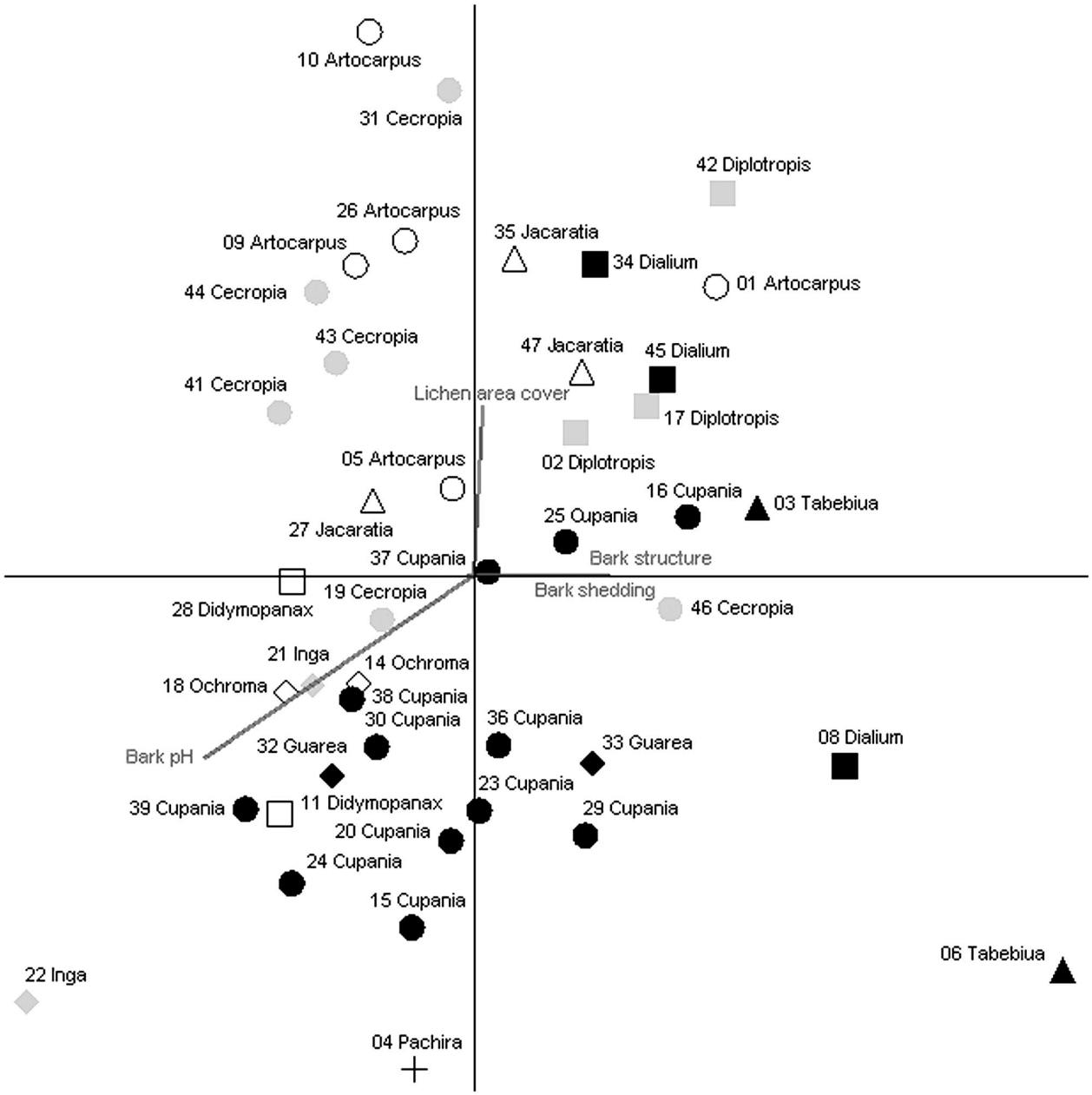

Fig. 7: Canonical correspondence analysis (CCA) plot of studied samples. Grey lines indicate correlations of principal axes with bark pH, bark structure, bark shedding, and lichen area cover, derived directly through linear correlation of species and sample scores axes with all measured parameters during the iteration process.

NMS, DCA, CCA, and cluster analysis for species instead of samples (not shown) did not indicate the formation of distinct communities. Accordingly, indicator species analysis of the main groups and subgroups detected in the cluster analysis shows that few lichen species have significant indicator values IV based on combined area cover and frequency within any of the groups (Table 5). *Cryptothecia striata* and *Diorygma poitaei* are significant indicator species of group A, and each of them of subgroup A1 and A2, respectively. Group B has two significantly indicative ($p < 0.05$) and five tendentially indicative ($p < 0.10$) species, among them *Fissurina instabilis*, *Pyrenula nitidula, Phyllopsora furfuracea* and *Porina curtula*. While the latter two are also indicative of subgroup B1, subgroup B2 has *Fissurina instabilis*, *Graphis glaucescens*, *Porina nucula*, and *Fissurina dumastii* as significant or tendential indicator taxa. Group C has *Porina conspersa*, *Malcolmiella polycampia* and *Porina internigrans* as indicator species, with subgroup C1 being characterized by *Byssoloma vanderystii*, *Porina internigrans*, and *Phyllopsora parvifolia*, and subgroup C2 by *Porina conspersa* and *Malcolmiella polycampia*. There is a slight systematic and morphological differentiation among indicator species of the three main groups: group A includes mostly taxa with effuse to byssoid,

ecorticate thallus, chiefly belonging to Arthoniales, while groups B and C have species with smooth to verrucose, mostly corticate thallus belonging to Pyrenulales, Ostropales (particularly group B with several Graphidaceae and group C with Porinaceae), and Lecanorales (particularly group C with several Pilocarpaceae).

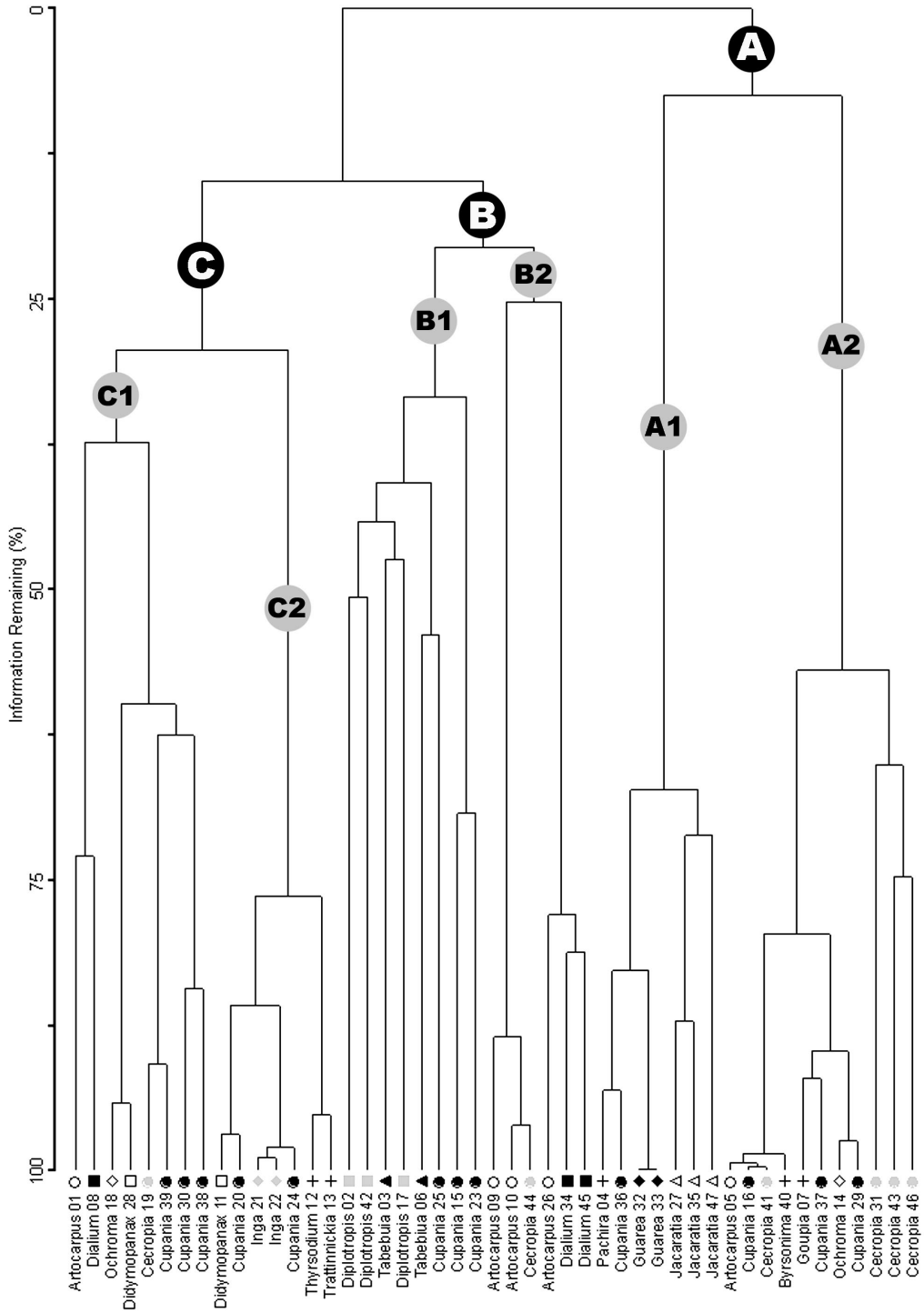

Fig. 8: Cluster dendrogram of studied samples based on relative Sørensen similarity values and flexible beta = –0.25. Main groups and subgroups are indicated.

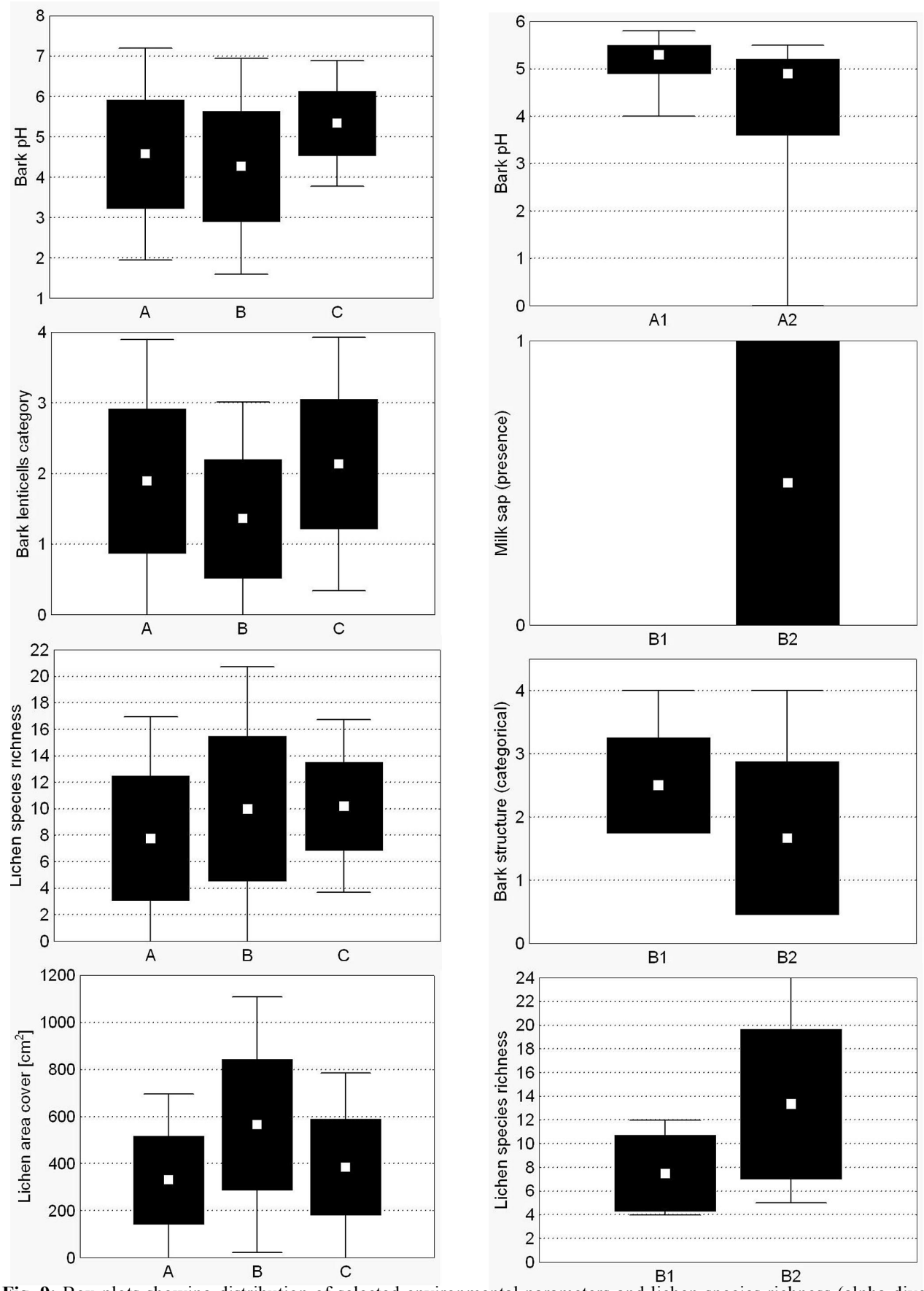

Fig. 9: Box-plots showing distribution of selected environmental parameters and lichen species richness (alpha-diversity) among the main groups and subgroups of the cluster dendrogram. Indicated are mean, STD, and 1.96 × STD.

Tab. 5: Indicator species analysis for main groups A–C and subgroups A1–C2 apparent from the cluster dendrogram (Fig. 8). Only species with $p < 0.2$ and a maximum of ten species per group/subgroup are shown.

	Observed IV	Expected IV	Std.Dev	p-level
Group A				
Cryptothecia striata	48.8	18.0	6.54	0.0010
Diorygma poitaei	57.3	24.2	6.46	0.0010
Dichosporidium nigrocinctum	26.9	21.0	8.18	0.2090
Subgroup A1				
Cryptothecia striata	93.6	16.8	7.13	0.0010
Arthonia bessails	27.8	13.7	7.15	0.0690
Subgroup A2				
Diorygma poitaei	73.3	19.4	6.75	0.0010
Cryptothecia spec. D (sterile)	23.1	18.3	8.95	0.2620
Group B				
Fissurina instabilis	26.1	10.6	5.14	0.0210
Thelotrema spec. A	25.7	13.4	5.96	0.0410
Pyrenula nitidula	20.6	9.9	5.26	0.0580
Herpothallon spec. C	14.3	7.6	3.45	0.0780
Opegrapha cf. *aperiens*	14.3	8.0	3.33	0.0800
Phyllopsora furfuracea	14.3	6.7	4.26	0.0860
Porina curtula	14.3	7.7	3.52	0.0870
Arthothelium aff. *chiodectoides*	13.9	8.9	4.74	0.1430
Chiodecton malmei	14.0	8.5	4.85	0.1430
Subgroup B1				
Phyllopsora furfuracea	25.0	10.5	5.97	0.0890
Herpothallon spec. C	25.0	12.9	5.55	0.0920
Porina curtula	25.0	12.7	5.36	0.0950
Subgroup B2				
Fissurina instabilis	61.9	12.3	6.85	0.0010
Graphis glaucescens	42.9	18.4	8.55	0.0200
Porina nucula	30.8	14.2	6.89	0.0290
Fissurina dumastii	27.3	15.9	8.05	0.0860
Coenogonium luteum	16.7	12.8	2.34	0.1110
Malcolmiella psychotrioides	16.7	12.7	2.42	0.1240
Malcolmiella piperis	24.3	16.5	7.63	0.1270
Astrothelium variolosum	16.7	12.7	2.50	0.1340
Anisomeridium americanum	16.7	12.8	2.49	0.1350
Platygramme scalpturata	16.7	12.8	2.49	0.1350
Group C				
Porina conspersa	92.1	27.2	6.60	0.0010
[sterile] spec. A (sorediate)	40.0	12.0	5.67	0.0010
Ocellularia spec. A (sorediate)	20.0	8.0	4.20	0.0340
Malcolmiella polycampia	20.0	8.4	4.34	0.0350
Porina internigrans	18.8	9.5	4.84	0.0650
Pyrenula mamillana	18.0	12.6	5.81	0.1450
Cryptothecia spec. E (sterile)	17.9	12.5	5.28	0.1560
Pyrgillus javanicus	13.3	7.2	3.92	0.1750
Byssoloma vanderystii	13.3	8.3	3.13	0.1890
Bapalmuia lafayettiana	13.3	6.6	4.21	0.1920
Subgroup C1				
Byssoloma vanderystii	25.0	14.1	4.77	0.0870
Cryptothecia spec. E (sterile)	22.0	13.4	6.62	0.1000
Porina internigrans	20.6	12.6	7.38	0.1420
Phyllopsora parvifolia	21.2	12.4	7.36	0.1570
Myriotrema costaricense	20.1	14.6	7.82	0.1810
Letrouitia domingensis	19.9	15.0	7.96	0.2250
Subgroup C2				
Porina conspersa	75.7	22.4	6.91	0.0010
[sterile] spec. A (sorediate)	48.1	14.0	7.42	0.0050
Malcolmiella polycampia	42.9	13.2	7.11	0.0070
Ocellularia spec. A (sorediate)	22.8	11.0	6.97	0.0800
Malcolmiella flavosorediata	15.4	12.0	6.74	0.2050

Eight out of 150 lichen species show significant ($p < 0.05$) or tendentious ($p < 0.10$) preferences towards certain tree species (Table 6). Among these are three *Cryptothecia* species, including *C. striata* and *C. subcandida*, which show preferences for *Guarea* and *Cecropia*, respectively, and two unidentified taxa being significantly more abundant on *Cecropia* and *Inga*. *Pertusaria* spec. (sorediate) and *Porina limitata* show preferences towards *Artocarpus* and *Cecropia*, respectively, while *Fissurina dumastii* exhibits a tendency towards *Artocarpus* as well. Thus, *Cecropia* is the tree species with the most distinctive preferences of lichen species.

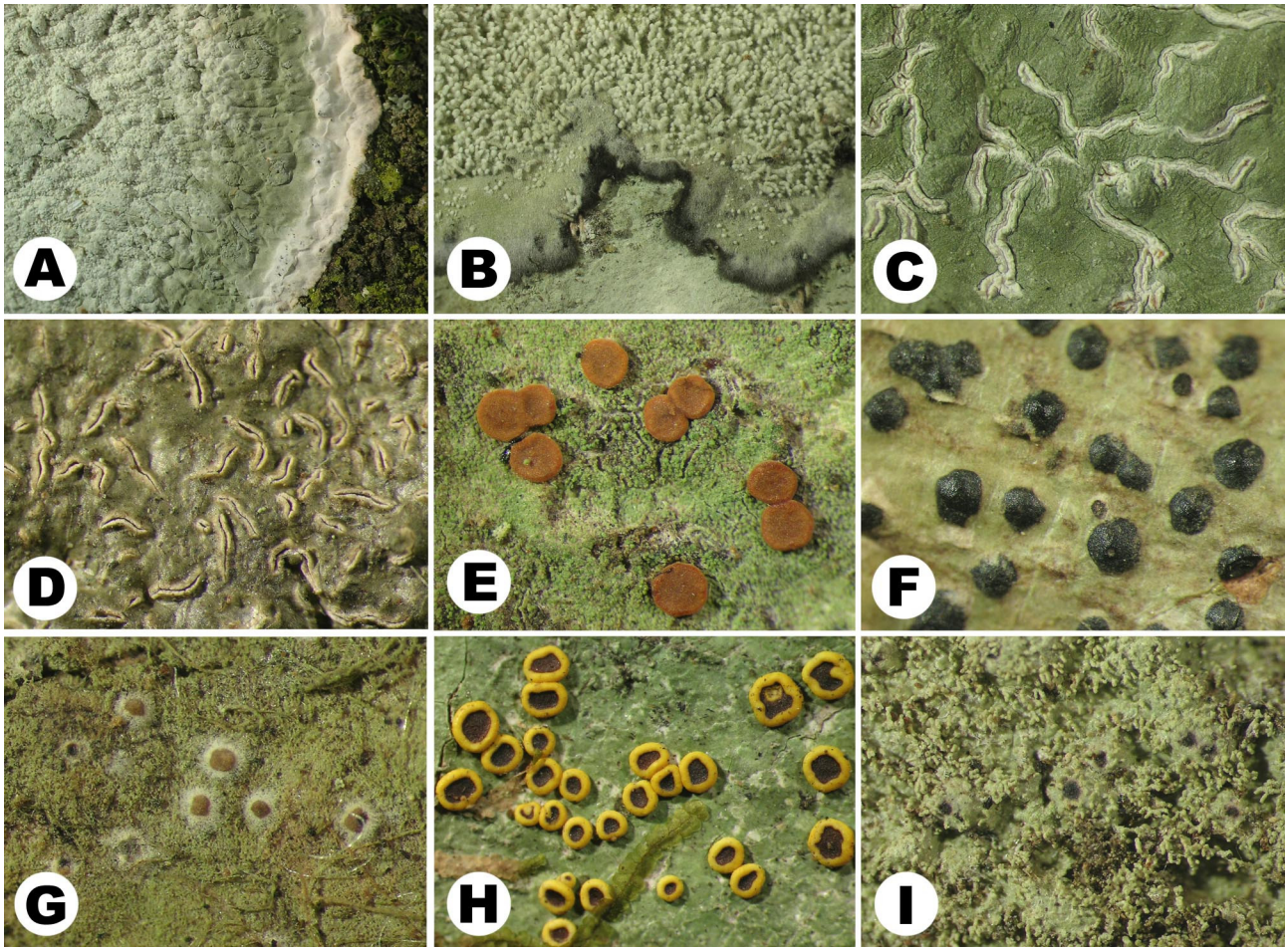

Fig. 10: Selected lichens characteristic of groups A, B, and C in the cluster dengrogram. A. *Cryptothecia striata*. B. *Dichosporidium nigrocinctum*. C. *Diorygma poitaei* (all group A). D. *Fissurina instabilis*. E. *Phyllopsora furfuracea*. F. *Pyrenula nitidula* (all group B). G. *Byssoloma vanderystii*. H. *Letrouitia domingensis*. I. *Porina conspersa* (all group C).

Tab. 6: Lichen species that show significant ($p < 0.05$) or tendential ($p < 0.10$) preferences towards certain tree species in the indicator species analysis, plus species with non-significant p-levels less than 0.3. For the tree species, only the genus names are indicated.

Species	Tree species	Observed IV	Expected IV	Std.Dev	p-level
Pertusaria spec. (sorediate)	*Artocarpus*	55.1	28.6	14.84	0.0460
Fissurina dumastii	*Artocarpus*	59.8	31.5	16.09	0.0760
Thelotrema spec. A	*Artocarpus*	45.1	32.7	16.48	0.1020
Graphis glaucescens	*Artocarpus*	36.3	30.8	14.91	0.2120
Porina limitata	*Cecropia*	50.0	30.2	14.20	0.0240
[unknown] spec. N (sterile)	*Cecropia*	50.0	29.9	16.80	0.0290
Cryptothecia subcandida	*Cecropia*	46.6	29.8	14.69	0.0480
Malcolmiella sorediata	*Cecropia*	47.5	30.9	17.86	0.1160
Diorygma poitaei	*Cecropia*	36.4	26.5	11.15	0.1950
Strigula stigmatella	*Cecropia*	37.8	30.9	14.63	0.2020

Malcolmiella piperi	*Cecropia*	36.1	27.7	13.02	0.2350
Mazosia ocellata	*Dialium*	41.7	30.1	13.35	0.2950
Opegrapha aff. *contracta*	*Didymopanax*	49.2	29.3	13.20	0.1000
Ocellularia spec. A (sorediate)	*Didymopanax*	35.5	29.2	13.58	0.2090
Porina conspersa	*Didymopanax*	39.5	30.3	11.05	0.2330
Cryptothecia striata	*Guarea*	81.7	32.4	16.39	0.0160
Dichosporidium nigrocinctum	*Guarea*	51.8	35.9	16.09	0.1720
[sterile] spec. A (sorediate)	*Inga*	95.8	30.1	14.76	0.0050
Cryptothecia spec. E (sterile)	*Ochroma*	63.9	25.4	12.57	0.0260
Byssoloma vanderystii	*Ochroma*	49.8	29.0	19.51	0.1510
[unknown] spec. N (sterile)	*Ochroma*	33.9	29.2	15.90	0.2320

Spatial and phorophyte-dependent beta-diversity

Beta-diversity, measured as relative Sørensen dissimilarity index, was relatively high on average among the tree samples, with more than 60% of the pairwise comparisons showing values higher than 0.9, that is 90% or more different species, and only 10% having values 0.5 and lower, that is sharing 50% or more of the species among samples (Fig. 11). Beta-diversity did not differ among categorical distance groups (Kruskal-Wallis ANOVA: $p = 0.574$; Median test: $p = 0.478$; Spearman $r = 0.031$, $p = 0.308$), although there is a very slight tendency for values among trees of the same group (distance group 0) being slightly lower (Fig. 12). However, beta-diversity values were highly significantly lower among samples belonging to the same tree species (Mann-Whitney U-test: $p < 0.001$) than among samples belonging to different tree species, with a median of 0.79 versus 0.98 (Fig, 13).

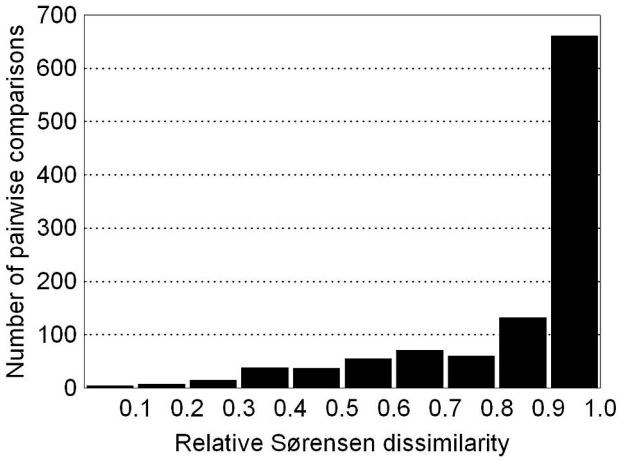

Fig. 11: Distribution of beta-diversity values (relative Sørensen dissimilarity) among all possible pairwise sample comparisons.

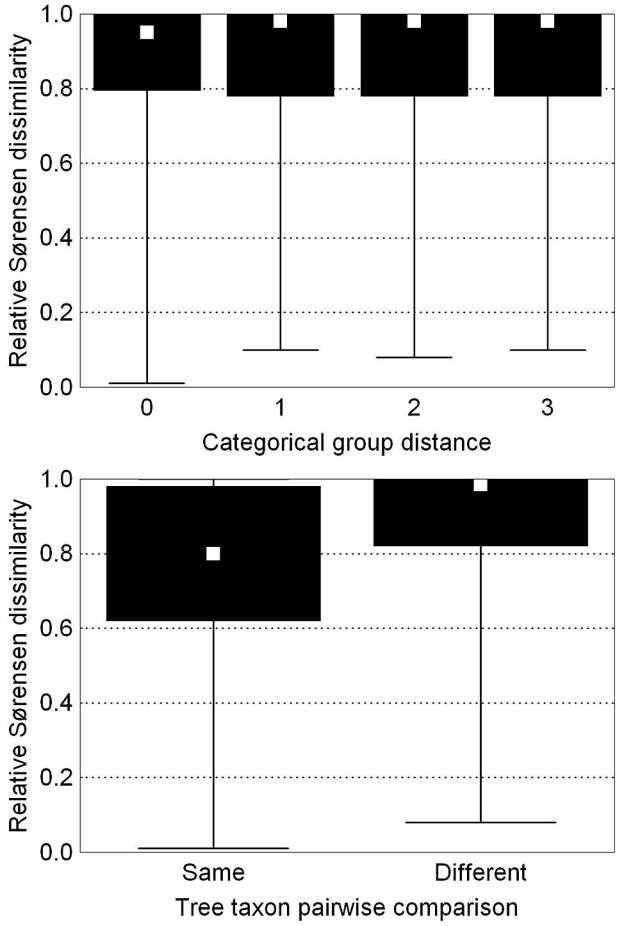

Fig. 12: Box-plots showing distribution of beta-diversity values (relative Sørensen dissimilarity) among all possible pairwise sample comparisons, differentiating between spatial distance categories (above) and tree species (below).

Correlation of species richness and area cover with environmental parameters

Individual correlation tests show that lichen species richness is positively correlated with the presence of milk sap and negatively with the degree of bark shedding (Table 7). Lichen area cover, on the other hand, is also positively correlated with the presence of milk sap, but negatively with bark pH and with the density and size of bark lenticels. This indicates that trees with milk sap (*Artocarpus* and *Cecropia*) have higher lichen species richness and area cover, increased bark pH and density of bark lenticels decrease area cover but have no effect on species richness, and increased bark shedding decreases species richness but has no effect on area cover.

Tab. 7: Spearman rank correlation between lichen species richness and area cover per sample and environmental parameters.

Environmental parameter	Species richness	Area cover
Diffuse site factor	—	—
Circumference	—	—
Direction	—	—
Milk sap	$r = 0.41$, $p < 0.05$	$r = 0.38$, $p < 0.05$
Bark pH	—	$r = -0.42$, $p < 0.05$
Bark water repellence	—	—
Bark structure	—	—
Bark lenticells	—	$r = -0.45$, $p < 0.05$
Bark shedding	$r = -0.44$, $p < 0.05$	—

Spearman rank correlation showed that environmental parameters were largely uncorrelated among themselves ($9 \times 8 / 2 = 36$ pairwise comparisons), except for direction vs. bark pH ($p < 0.05$), bark pH vs. bark lenticels ($p < 0.05$), milk sap vs. bark lenticels ($p < 0.05$), and bark lenticels vs. bark shedding ($p < 0.05$). Accordingly, the results from multiple regression of lichen species richness and area cover versus environmental parameters are slightly different from those obtained by individual correlations. Lichen species richness is positively correlated with environmental parameters ($r = 0.69$, $p < 0.05$), but significant components of beta were only found for diffuse site factor (beta = 0.33, $p < 0.05$) and bark shedding (beta = –0.58, $p < 0.001$). Compared to individual correlations, multiple regression thus shows an increased negative effect of bark shedding and an otherwise undetected positive effect of diffuse site factor on lichen species richness. On the other hand, lichen area cover is only tendentiously correlated with environmental parameters ($r = 0.51$, $p = 0.068$), and no significant components of beta were detected for any of the environmental parameters. This suggests that invididual correlations are partially obscured by inverse effects of uncorrelated environmental parameters on lichen area cover.

Lichen species richness (alpha-diversity) showed a positive linear correlation with area cover (Pearson correlation: $r = 0.29$, $p < 0.05$). However, a non-linear model applying a negative parabolic approximation going through the origin (Fig. 13) gives a slightly better fit ($r = 0.34$, $p < 0.05$), indicating that lichen species richness increases with lichen area cover in a linear fashion for low values of lichen area cover but reaches a maximum and then slowly decreases with high values of lichen area cover.

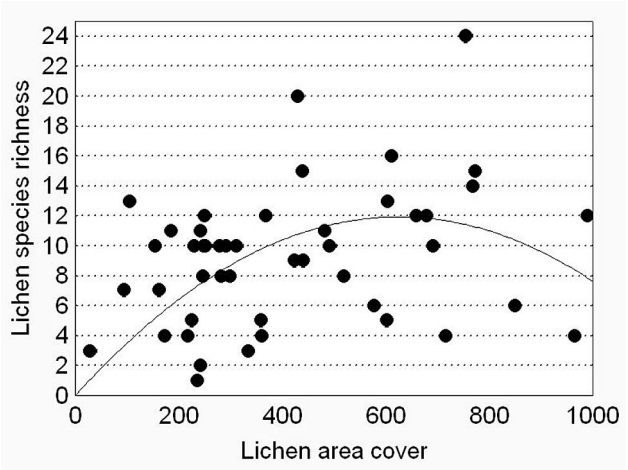

Fig. 13: Negative parabolic relationship between lichen species richness (alpha-diversity) and area cover.

Discussion

The total number of corticolous crustose microlichen species found at the study site is among the highest ever reported for a tropical rainforest site, thus far surpassed only by the study of KOMPOSCH & HAFELLNER (1999, 2000, 2002) in Venezuela and by the 173 species found on a single tree in Papua New Guinea (APTROOT 1997), as well as by two recent studies in Costa Rica (LIZANO et al., in prep.; MONCADA et al., in prep.). On the other hand, average and maximum sample alpha-diversity, with 8.6 species per sample and a maximum of 24 taxa, is comparatively low, indicating a high degree of beta-diversity between samples, which was confirmed by the analysis of beta-diversity values ranging mostly above 0.9 or 90% dissimilarity. The relatively low number of 47 studied trees suggests that beta-diversity, that is sample heterogeneity, contributes much more to overall diversity than alpha-diversity of individual samples. NOESKE (2004) studied the lichen and bryophyte species compositions of 30 phorophytes in Ecuador, analyzing different sample areas in each tree. She found for the microlichens a variation from 13–34 species per phorophyte. However, total lichen diversity was much lower (45 species) in comparison with the present work, suggesting that alpha-diversity contributed more to overall diversity than sample heterogeneity. Similar results were also found in other studies (CORNELISSEN & TER STEEGE 1989; MONTFOORT & EK 1990; WOLF 1993a–c, 1994, 1995; BIEDINGER & FISCHER 1996; HOLZ & GRADSTEIN 2005). These differences are probably due to the effort made in the present study to identify all crustose lichens to species level, which increases the number of rare species and thus automatically increases the level of sample heterogeneity and beta-diversity.

In agreement with this is the extremely high proportion of rare to very rare species, higher than in most other comparable studies. No less than 86% of the species are rare (found in 10% of the samples or less), and 54% are extremely rare, found in a single sample only. About half of the species each cover less than 5×5 cm^2, of a total sample area of 60,000 cm^2. This indicates that most species found within the transect have a strategy of low population density and high spatial dispersion of individuals, probably to escape competition from the dominant lichens, such as *Diorygma poitaei*, *Porina conspersa*, and *Graphis glaucescens*. As mentioned, these rare species add a significant component of stochasticity to the data and partly explain the absence of strong community patterns. It is therefore often suggested to exclude rare species from community ecology analyses (GREIG-SMITH 1978; GAUCH 1982; JONGMAN et al. 1995; MCCUNE & GRACE 2002), but on the other hand they make up a significant component of taxonomic diversity and are indispensable for considerations of conservation of biodiversity.

The multivariate community analysis suggests that, while there is no evidence of phorophyte specificity among the studied lichens, subtle differences in lichen species composition exist among different tree species and these can be explained to a large degree by preferences towards certain bark characteristics, in particular bark pH, but also bark structure, lenticels, and degree of bark shedding, as well as water repellence. This is confirmed by the pairwise analysis of beta-diversity values among trees of the same vs. different species, although average dissimilarity values among samples of the same tree species are still comparatively high. The spatial autocorrelation analysis of beta-diversity values also demonstrates that there is practically no effect of spatial distance on sample dissimilarity, except for a very slight decrease of beta-diversity among samples belonging to trees within the same spatial group. In other words, beta-diversity is equally high among proximal and among distant samples, with a minimum distance of 0.5 m and a maximum distance of about 500 m between the sampled trees. This contradicts the notion that within the closed rainforest, lichens often disperse locally through rainwater and thus form local population clusters, as found, for example, in foliicolous lichen communities (LÜCKING 2001).

As a result, no distinct lichen community structure was found in the present study, except for the few species that showed patterns of phorophyte or group preferences. This in at least in part due to the predominance of rare taxa, whose distribution is either stochastic or their abundance and frequency values are too low to result in statistically significant patterns of community preferences. This results in associations that actually share most of the lichen species or have taxa with low, statistically not significant steadiness values, but differ in a few, moderately abundant to common taxa, such as *Cryptothecia striata* and *Diorygma poitaei* for group A, *Fissurina instabilis*, *Pyrenula nitidula, Phyllopsora furfuracea* and *Porina curtula* for group B, and *Porina conspersa*, *Malcolmiella polycampia* and *Porina internigrans* for group. The morphological and taxonomic differentiation between these species, group A with effuse to byssoid, ecorticate thalli, chiefly Arthoniales, groups B and C with smooth to verrucose, mostly corticate thalli belonging to Pyrenulales, Ostropales (group B), and Lecanorales (group C), is intriguing, but requires more detailed studies in a setting with more pronounced differences in environmental parameters to test for correlations. In tropical crustose folicolous lichens, such correlations have been shown to exist, in particular between thallus morphology and microclimatic parameters such as diffuse site factor (LÜCKING 1999b, c).

The absence of strong patterns of phorophyte specificity can be explained in various ways. While similar results were found in other studies (CORNELISSEN & TER STEEGE 1989; MONTFOORT & EK 1990; WOLF 1993a–c, 1994, 1995; BIEDINGER & FISCHER 1996; HOLZ & GRADSTEIN 2005), it was also found that lichen community parameters correlate with bark nutrient content and bark chemistry, parameters which were not studied here. However, nutrient content is

usually measured as parameter of the bark humus layer, which is well-developed in montane rainforests on branches and trunks loaded with epiphytes (WOLF 1993a–c, 1994, 1995; NADKARNI 2000), but usually absent in lowland rainforests with a pronounced dry season, as in the present case. Research on foliicolous lichens showed the absence of phorophyte specificity in most species but a strong correlation of species richness with substrate age and of species composition with relative light intensity (LÜCKING 1998a–b, 1999a–c). This was not observed for the corticolous lichens in the present study, probably because all of the included trees were mature and of comparable age, and because strong variation in light patterns, including large light gaps and exposed canopy, were absent. This lack of variation was, however, intentional of the study to not obscure potential patterns of phorophyte preferences and specificity themselves.

The aforementioned high degree of stochasticity, expressed by the very high beta-diversity values, is another factor obscuring patterns of potential phorophyte specificity, since it implies that many lichen species, because of their rareness and dispersal strategies, are absent from samples where they would find favorable growth conditions. A forth factor is suggested by the indicator species analysis, which shows that the degree of community preference or potential phorophyte preferences varies among species, with most species having broad ranges while only a few, for example *Cryptothecia striata*, *C. subcandida*, *Dichosporidium nigrocinctum*, *Diorygma poitaei*, *Fissurina dumastii*, *Porina conspersa*, and *Porina internigrans*, show tendential to significant preferences. Accordingly, the number of lichen species that differentially characterize groups A, B, and C in the cluster analysis is between 10 and 20, compared to the total number of 150 species found. This results in a pattern where lichen communities are relatively undifferentiated across phorophyte species in terms of overall species composition, but differ by a few, characteristic taxa each. In a multivariate analysis, such a pattern would result in certain groups based on tree species in ordination plots, where relative distance between all data points is projected, but the absence of clear patterns in a cluster analysis, where the relative distance of data points is lost, as observed in the present study.

In spite of the high degree of stochasticity and the strong variation of lichen species richness relative to lichen area cover, the non-linear estimation supports findings of other studies, including foliicolous lichens (LÜCKING 1998a), that lichen species richness decreases with high values of lichen area cover, most probably due to increasing competition of dominant species that produce large thalli outcompeting other species. This is in accordance with the dynamic equilibrium hypothesis of species diversity (HUSTON 1979).

The variation of certain bark characteristics within a tree species, such as bark pH and even bark structural parameters, and the observed correlations of sample points and sample clusters with these and other environmental parameters, indicate that potential phorophyte preferences are not due to specific relationships between lichen and tree species, but rather to preferences for certain bark characteristics, which might be shared between different tree species. If that is the case, high tree diversity would obscure such preferences, since higher tree diversity implies fewer differences between individual trees with regard to bark characteristics. One would then expect for tropical forest ecosystems with high tree diversity to show less evident patterns of lichen phorophyte preferences or even phorophyte specificity than found in temperate regions with low tree diversity (BARKMANN 1958; ADAMS & RISSER 1971; BRODO 1973; JONES 1980; ESSEEN 1981; SCHMITT & SLACK 1990; WIRTH 1992; HAMADA et al. 1995; LOPPI & FRATI 2004; PECK et al. 2004). It can also be assumed that the presence of phorophyte specificity or strong phorophyte preferences would reduce the probability of successful establishment of a lichen species, considering that diaspore dispersal is largely stochastic and high tree diversity decreases the abundance of a suitable substrate.

Based on these findings, the following model scenario for community formation in tropical crustose rainforest microlichens might be considered. Depending on their growth (endo- or epiphloedic) and hence their contact with the substrate, as well as their thallus structure, lichen species show different degrees of phorophyte preferences and in some cases probably even phorophyte specificity, which correlate with morphological and chemical bark characteristics. However, these patterns are overlayed by several factors, including variation of microclimatic parameters and age-dependent variation of tree bark characteristics. While these two, largely independent layers of variation would be well-resolvable in a multivariate study, they are obscured to a large degree by stochastic patterns and individual sample history, including diaspore dispersal, spatial dispersion of rare species, interspecific interactions including, but not limited to, competition, and interactions with other organisms, such as lichen feeders and lichen parasites (LAWREY 1980, 1983; RAMBOLD 1985; ARMSTRONG 1986, 1988; ROGERS 1988; PFLEIDERER & WINKLER 1991; HARRIS 1996; LÜCKING & BERNECKER-LÜCKING 2000). The findings of subtle phorophyte preferences of the lichen communities in the present study therefore suggests that the underlying correlations with phorophyte features are stronger than apparent, and experimental studies limiting the effects of stochasticity are required to assess those underlying correlations.

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EFFICIENCY OF SAMPLING METHODS FOR ACCURATE ESTIMATION OF SPECIES RICHNESS: CORTICOLOUS MICROLICHENS IN THE ATLANTIC RAINFOREST OF NORTHEASTERN BRAZIL

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Abstract. Three different sampling methods were compared with regard to accurate estimation of species richness of crustose and microfoliose lichens in the Atlantica rainforest of northeastern Brazil. Quantitative transect sampling yielded more than three times as many species (150) as non-quantitative opportunistic sampling of ecologically equivalent sites on average (40), even if the number of sampled phorophyte trees (75 vs. 47) was higher on average for the latter method. Repetitive non-quantitative opportunistic sampling of a single site resulted in more than twice the number of species (99) than one-time sampling of ecologically equivalent sites (40), but only two thirds of the number recovered by means of quantitative transect sampling, even of the number of sampled phorophyte trees (150) was highest for this method. The analysis showed that opportunistic sampling fails to detect rare, inconspicuous, sterile, and/or cryptic species, which are usually neglected or overlooked even by the experienced collector upon visual inspection in the field, while quantitative sampling forces even the inexperienced collector to sample lichen thalli or pieces of bark which only in the laboratory, after detailed morphological, anatomical, and chemical study, reveal themselves as distinct species. Accordingly, of the 456 lichen species collected and identified across the 22 studied localities, no less than 76 were unique to the quantitatively sampled transect, and the lichen species sampled with this method had a significantly higher proportion of rare, inconspicuous, sterile, and/or cryptic species. It is also apparent that it is not the higher number of specimens collected via quantitative sampling that results in a higher number of species, but the method of selection of the specimens, which is subjective and biased towards abundant, conspicuous, fertile and/or distinctive species in opportunistic sampling, but objective and unbiased in quantitative sampling.
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Key words: Alagoas, Biodiversity, crustose lichens, opportunistic sampling, Pilar, quantitative sampling, repetitive sampling, RPPN Fazenda São Pedro

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INTRODUCTION

It is believed that lichens are among the few organisms whose diversity decreases towards tropical latitudes. However, recent studies indicate that the opposite is the case and that the highest small-scale lichen diversity is found in tropical lowland rainforests. Inventories of Costa Rican and Venezuelan rainforests indicate a number of 400–600 species per site (Komposch & Hafellner 1999, 2000, 2002, Moncada *et al.*, in prep.; Lizano *et al.*, in prep.), and Aptroot (1997) found 173 species on a single tree, figures that are not observed in extratropical areas. The total number of lichens estimated to occur in megadiverse countries such as Colombia and Papua New Guinea ranges somewhere between 3,000 and 4,000, almost twice as many than known for the British Islands or Scandinavia (Purvis *et al.* 1992, Santesson 1993). Costa Rica is only a fraction of the size of Germany, but has probably about 50% more lichen species (Lücking *et al.* 2004).

A large proportion of tropical lichen diversity is made up by corticolous and microfoliose lichens (Sipman & Harris 1989, Sipman 1996) whose taxonomy, especially of crustose taxa, has largely been neglected. Therefore, reliable estimates of tropical lichen diversity are difficult, and detailed studies reveal numbers much higher than previously predicted. For example, Santesson (1952) lists a number of 236 species of foliicolous lichens world-wide, a number that has more than tripled since then (Lücking 2003, 2007). An ongoing inventory in Costa Rica reveals numbers about twice as high as predicted for selected groups of corticolous lichens, such as the genera *Graphis* (110 species; Lücking *et al.* 2007), *Gyalideopsis* (30 species; Nelsen *et al.* 2006) and the microfoliose Physciaceae (more than 100 species; Will-Wolf *et al.*, in prep.).

The diversity of the lichen biota of Brazil is estimated to exceed 4.000 species, and the current state of knowledge is published online as a checklist compiled by Marcelo Marcelli and Tassilo Feuerer (http://www.biologie.uni-hamburg.de/checklists/southamerica/brazil_l.htm). Biotic surveys have been also undertaken recently in a number of Mata Atlântica remnants in northeastern Brazil (Pereira *et al.* 2005a–c), although the results are still far beyond than the expected lichen richness of about 1,000 species for the area. Besides the unsettled taxonomy concerning the identification of tropical crustose microlichens, another crucial factor influencing correct estimation of lichen diversity is the sampling methods employed. Several studies suggest that subjective opportunistic sampling by specialists yields less species than objective systematic sampling, such as applying a transect, grid, or stratified sampling technique (Gradstein *et al.* 1996, Sipman 1996, Newmaster *et al*. 2005). A further problem is that even with quantitative sampling, employed in a number of recent studies on tropical lichens (Cornelissen & Ter Steege 1989, Montfoort & Ek 1990, Marcelli 1992; Wolf 1993a–c, 1994, 1995, Biedinger & Fischer 1996, Wolseley & Aguirre-Hudson 1997, Nöske 2004, Nöske & Sipman 2004, Holz & Gradstein 2005), crustose microlichens are often left unidentified at the species level, and thus a significant component of species richness is neglected. The only exception is the detailed study of crustose and foliose lichen communities by Komposch & Hafellner (1999, 2000, 2002) in Venezuela, which yielded about 300 species for the study site.

In the present paper, data from a survey of 22 localities in northeastern Brazil, as well as from an ecological transect study (Cáceres 2007, Cáceres *et al.* 2007a, b) are used to analyse the effect of three different sampling techniques on the number of lichen species recovered: non-quantitative opportunistic sampling, repetitive non-quantitative opportunistic sampling at a single site, and quantitative transect sampling at a single site. Apart from comparing the resulting number of species by each method, we also introduced a combined score for each lichen species with regard to abundance, conspicuousness, fertility, and distinctiveness, in order to test whether different sampling methods recovered rare, inconspicuous, sterile, and/or cryptic species at different proportions and how much such species contribute to the overall diversity of a given site.

MATERIAL AND METHODS

The analysis was carried out using the data from 17 rainforest remnants representing the Atlantic rainforest or Mata Atlântica (Zona da Mata and Brejos de Altitude) vegetation in northeastern Brazil, plus five localities representing Caatinga vegetation (Fig. 1). The study area and collecting sites are described and listed in other parts of this work (Cáceres 2007, Cáceres *et al.* 2007a, b). The field work took place during three field campaigns to northeastern Brazil from October to November 2000, April to May 2001 and September to October 2002.

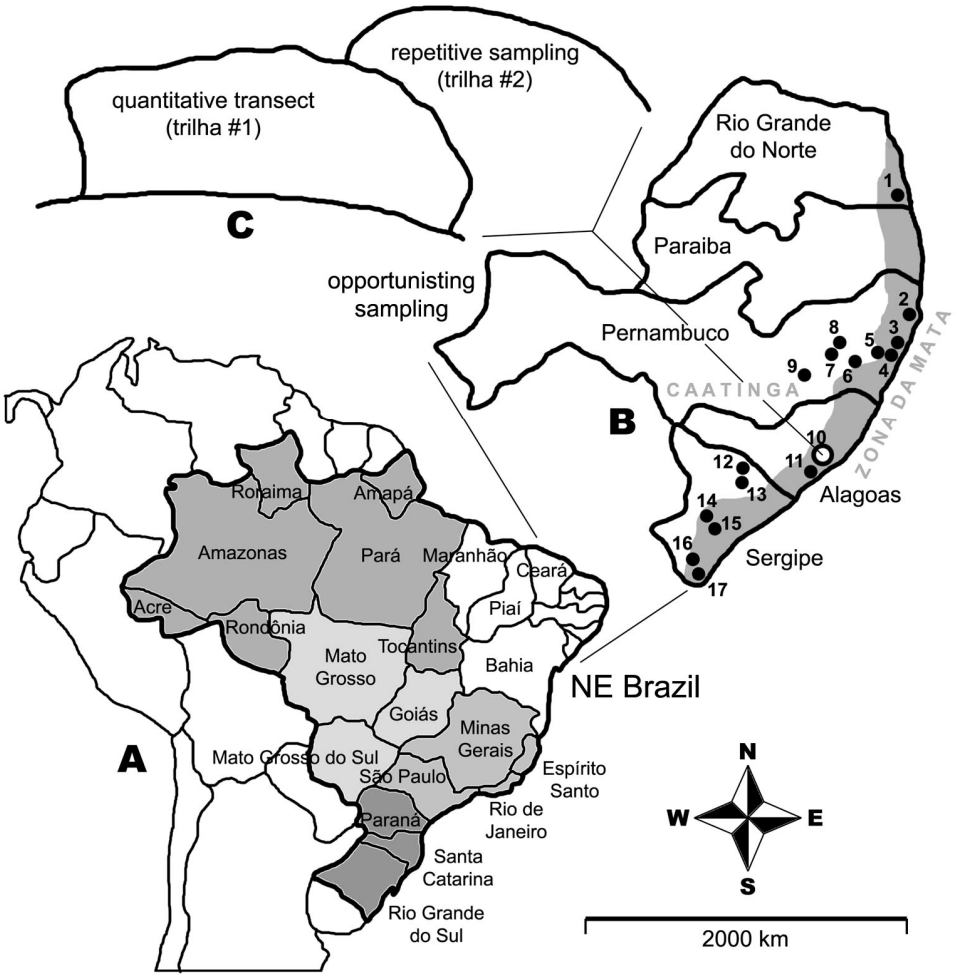

FIG. 1. A: Brazil and its five regions. B: The eastern coastal states with localities studied by opportunistic sampling (3 of the 17 dots indicate 2 localities each and one 3 localities, for a total of 22). C: The two trails additionally sampled at RPPN Fazenda São Pedro for repetitive and quantitative sampling. The first visit to this site was also counted as opportunistic sampling.

Three different sampling methods were employed: (I) one-time non-quantitative opportunistic sampling per site ('opportunistic'), (II) three-times repetitive non-quantitative opportunistic sampling at a single site ('repetitive'), and (III) quantitative transect sampling at a single site ('quantitative'). Opportunistic sampling was applied to inventory the corticolous lichen diversity of 22 remnants of Mata Atlântica, Caatinga and Brejos de Altitude vegetation in the states of Rio

Grande do Norte, Pernambuco, Alagoas and Sergipe in northeastern Brazil (Fig. 1). This method followed the suggestions made by Sipman (1996), with phorophyte trees selected along the main trails within the rainforest fragments as well as penetrating the vegetation when possible. Phorophyte trees were approached both randomly and based on visual selection through the presence of conspicuous lichen thalli, and each tree was inspected for about 3–5 minutes. Specimens were collected of all lichen thalli recognized as different from each other in the field, usually 1–5 per tree. With this method, a number of 50–100 phorophyte trees per locality was analyzed and about 100–200(–300) lichen samples collected per locality. Repetitive sampling was applied to one site, the trilha #2 at RPPN Fazenda São Pedro in Pilar, Alagoas (Fig. 1), which was visited three times to assess the effect of multiple visits on the lichen diversity inventoried.

Quantitative sampling was employed at the same site, the RPPN Fazenda São Pedro, although a different, parallel, non-overlapping trail, the trilha #1 (Fig. 1), to study potential phorophyte preferences of corticolous lichens (Cáceres *et al.* 2007b). Collections were made along a transect laid on one of the main trails. A total of 47 phorophytes belonging to 16 different tree species were selected. Sample rectangles of 60 × 20 cm^2 each were placed on the trunk of each phorophyte at breast height. All lichen thalli located inside each of the 47 sample rectangles were registered and identified to species level using morphological, anatomical and chemical characters (Cáceres *et al.* 2007b). The main difference between methods I and II was the number of phorophytes studied and the number of collected lichen samples (Table 1), in addition to the fact that for method II, the same area within the site and partially the same phorophytes were revisited and resampled based on previous sampling experience. The main difference of method III was the different approach towards the selection of phorophytes and lichen specimens by means of sample rectangles, within which all lichen specimens were identified (Table 1). As a result, the number of studied phorophytes is lowest in method III and highest in method II, while the total number of collected and identified specimens per site was highest in method III and lowest in method I. However, the average number of lichen specimens per phorophyte was highest in method III.

TABLE 1. Comparison of three different sampling techniques to assess lichen species richness.

Sampling parameters	Non-quantitative opportunistic sampling (method I)	Repetitive non-quantitative opportunistic sampling (method II)	Quantitative transect sampling (method III)
Selection of phorophytes	subjective	subjective (refined)	systematic
Phorophytes per site	≈ 50–100	≈ 150	≈ 50
Selection of lichen specimens	visual in situ	visual in situ (refined)	sample presence
Lichen specimens per site	100–200(–300)	≈ 450	≈ 550
Lichen specimens per phorophyte	≈ 1–5 (∅ 2)	≈ 1–10 (∅ 3)	≈ 1–45 (∅ 11)
Identification of species	selective	selective (refined)	all

All lichen species were scored with respect to four binarily coded parameters: (1) abundance (abundant versus rare), (2) conspicuousness (conspicuous versus inconspicuous), (3) fertility (commonly fertile versus commonly sterile), and (4) distinctiveness (recognizable as distinct species versus cryptic). Abundance was assessed based on the total number of collected specimens in combination with the number of sites where a species was collected. Conspicuousness was based on the notion whether a thallus of a given species was usually visible from a certain distance in the field or only at close-up or through a hand lens or stereomicroscope. Fertility referred to the usual presence or absence of ascomata necessary for identification, and distinctiveness separated macroscopically recognizable from cryptic species (Table 2). These assessment were based on the

hypothesis that species are more likely to be collected by opportunistic sampling if they are abundant, conspicuous, fertile (sterile specimens more commonly being rejected because of less likeliness of positive identification), and/or distinctive as species, while rare, inconspicuous, commonly sterile and/or cryptic taxa are more likely to be collected by quantitative sampling.

TABLE 2. Assessment of four lichen species specific parameters.

Parameters	Binary states	Determination	Examples
Abundance	abundant (1)	≥ 5 specimens or ≥ 3 specimens and ≥ 2 sites	*Dichosporidium nigrocinctum* *Diorygma poitaei* *Glyphis cicatricosa* *Ocellularia bahiana* *Sarcographa labyrinthica*
	rare (0)	> 5 specimens or > 3 specimens and > 2 sites	*Acanthotrema brasilianum* *Ampliotrema amplius* *Enterographa* spp. *Hemithecium chlorocarpum* *Plectocarpon syncesioides*
Conspicuousness	conspicuous (1)	visible with naked eye from 3 m distance	*Arthonia platygraphidea* *Dyplolabia afzelii* *Letrouitia domingensis* *Sagenidiopsis undulata* *Trypethelium eluteriae*
	inconspicuous (0)	visible at close-up or with handlens only	*Bacidina* spp. *Celothelium aciculiferum* *Cryptolechia nana* *Fellhanera* spp. *Ramonia intermedia*
Fertility	fertile (1)	with distinct ascomata	*Bathelium madreporiforme* *Lecanactis epileuca* *Malcolmiella psychotrioides* *Porina nucula* *Sclerophyton elegans*
	sterile (0)	lacking ascomata	*Chrytothrix* spp. *Cryptothecia* spp. *Herpothallon* spp. sorediate Thelotremataceae unknown species
Distinctiveness	distinctive (1)	macroscopically recognizable	*Anomomorpha aggregans* *Brigantiaea leucoxantha* *Coniocarpon cinnabarinum* *Phaeographis haematites* *Pyrenula anomala*
	cryptic (0)	microscopically or chemically recognizable	*Anisomeridium* spp. *Coenogonium* spp. *Graphis* spp. *Opegrapha* spp. *Porina* spp.

For each species, the four binary codes were added to a combined score CS, ranging from 0 (species rare, inconspicuous, sterile, and cryptic) to 4 (species abundant, conspicuous, fertile, and distinctive). Since the individual states for each parameter are independent of each other, any combination of codes is possible, for a total of $2^4 = 16$ combinations (Table 3). Examples for combined score = 0 include all the sterile taxa (30 out of a total of 456) that were recognized as distinct species based on their morphology, anatomy, and chemistry, but could not be named due to the lack of critical systematic characters. Examples for combined score CS = 4 include *Chapsa dilatata*, *Cryptothecia striata*, *Dichosporidium nigrocinctum*, *Glyphis cicatricosa*, *Graphis chrysocarpa*, *Helminthocarpon leprevostii*, *Hemithecium chrysentheron*, *Lecanora caesiorubella*, *Lecanactis epileuca*, *Letrouitia domingensis*, *Malcolmiella badimioides*, *Maronina multifera*, *Ocellularia bahiana*, *Ochrolechia africana*, *Phaeographis haematites*, *Pyrenula mamillana*, *Sarcographa labyrinthica*, and *Trypethelium tropicum* (Fig. 2).

TABLE 3. Calculation of combined score for selected lichen parameters.

Abundance	Conspicuousness	Fertility	Distinctiveness	Combined score CS	Example
0	0	0	0	**0**	*Malcolmiella polycampia*
0	0	0	1	**1**	*Ocellularia* sp. (red soralia)
0	0	1	0	**1**	*Bactrospora macrospora*
0	1	0	0	**1**	*Herpothallon sp.*
1	0	0	0	**1**	*Porina conspersa*
0	0	1	1	**2**	*Bacidina penicillata*
0	1	0	1	**2**	*Cryptothecia punctosorediata*
1	0	0	1	**2**	[no species found]
0	1	1	0	**2**	*Graphis striatula*
1	0	1	0	**2**	*Arthopyrenia chinchonae*
1	1	0	0	**2**	*Chryothrix xanthina*
0	1	1	1	**3**	*Haematomma leprarioides*
1	0	1	1	**3**	*Chapsa alborosella*
1	1	0	1	**3**	*Herpothallon rubrocinctum*
1	1	1	0	**3**	*Cresponea leprieurii*
1	1	1	1	**4**	*Laurera megasperma*

Depending on their presence/absence within the localities for which the different sampling methods were applied, the 456 lichen species were classified into seven different categories (Table 4). In addition, species found in Caatinga vegetation only were assigned to a separate category, since repetitive and quantitative sampling were applied to a Mata Atlantica site and absence of Caatinga species from this site (and sampling methods) is due to ecological reasons rather than sampling technique. Exclusive Caatinga species in this study include *Anismeridium tamarindii*, *Arthopyrenia chinchonae*, *Cratiria obscurior*, *Hafellia curatellae*, *Lecanographa lyncea*, *Lecanora caesiorubella*, *Ochrolechia africana*, *Phaeographis punctiformis*, and *Stigmatochroma gerontoides*, among others.

For each of the seven categories plus the Caatinga category, the relative proportion of species with different combined scores of lichen parameters (CS = 0, 1, 2, 3, 4) was calculated, and a Chi-Square test of observed versus expected frequencies was applied to test for significant differences in relative proportion of scores between categories.

Statistical analysis was performed in STATISTICA™ 6.0.

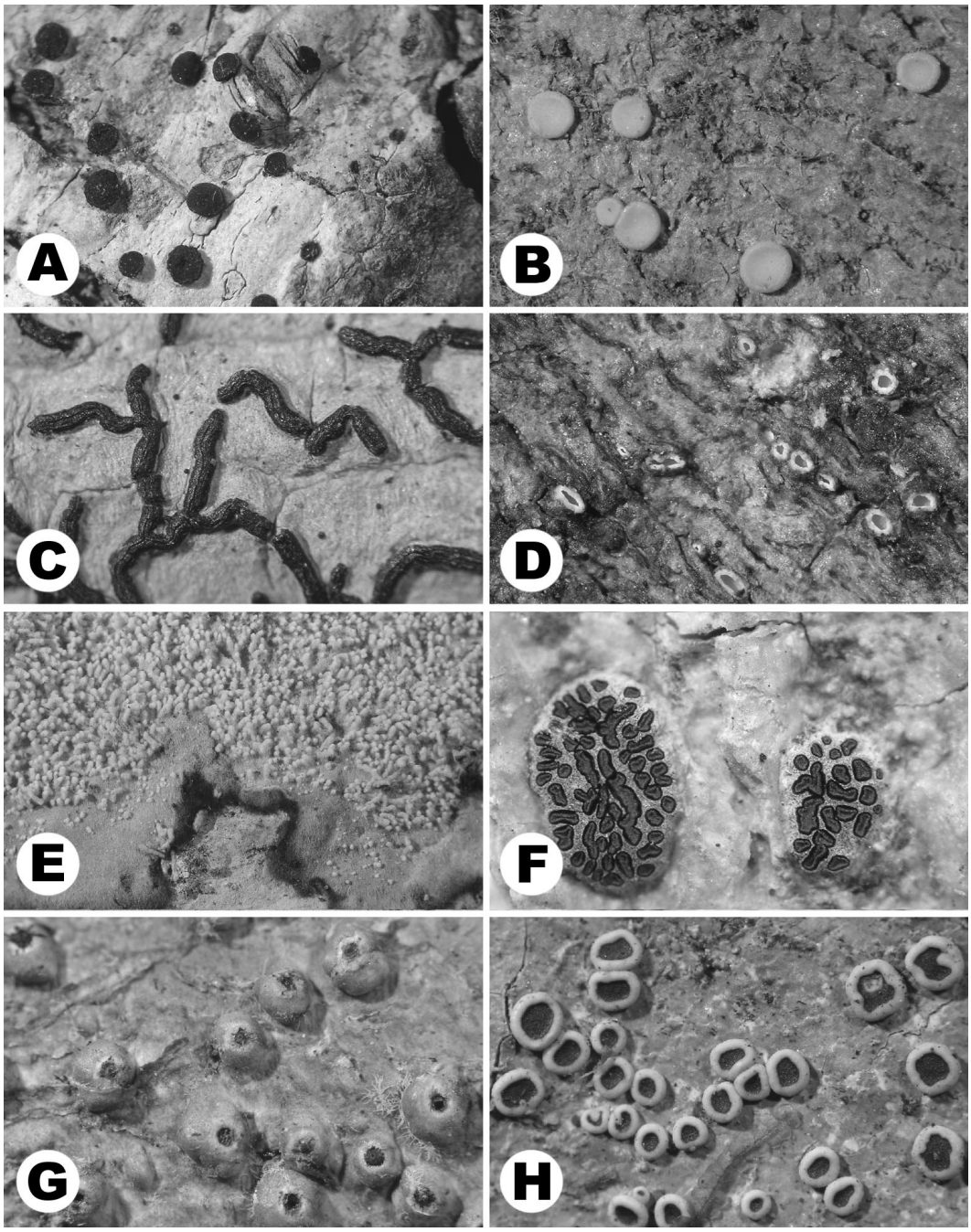

FIG. 2. Examples of lichen species with low (A–D) and high (E–H) combined scores CS. A: *Bactrospora myriadea* (rare, cryptic). B: *Coenogonium pyrophthalmum* (rare, cryptic). C: *Graphis dupaxana* (rare, cryptic). D: *Ramonia intermedia* (rare, inconspicuous). E: *Dichosporidium nigrocinctum*. F: *Glyphis cicatricosa*. G: *Laurera megasperma*. H: *Letrouitia domingensis*.

TABLE 4. Assignment of lichen species to seven different categories dependent on presence / absence within localities for which the three different sampling methods were applied (Caatinga species category not shown).

Method I (21 localities)	Method II (1 site)	Method III (1 transect)	Distribution code	Category	Example
present	—	—	×–o–o	A	*Anthracothecium prasinum*
present	present	—	×–×–o	B	*Pyrenula ochraceoflava*
present	present	present	×–×–×	C	*Porina internigrans*
present	—	present	×–o–×	D	*Cryptothecia effusa*
—	present	—	o–×–o	E	*Squamacidia janeirensis*
—	present	present	o–×–×	F	*Myriotrema myriotremoides*
—	—	present	o–o–×	G	*Cryptolechia nana*

RESULTS

A total of 456 species of corticolous crustose and microfoliose lichens were found in the entire study area and combining the results of all three sampling techniques I–III. The number of species per site varied strongly among localities, but by far the highest number was found within the transect (method III) at RPPN Fazenda São Pedro (150 species) and the second highest number within the repetitively collected area (method II), also at RPPN Fazenda São Pedro (99 species). The localities with the highest number of species found by opportunistic sampling (I) were the two Brejos de Altitude (Brejo dos Cavalos, Bonito), with 84 and 73 species, respectively, followed by the Zona da Mata and Caatinga sites (Fig. 3). Apart from RPPN Fazenda São Pedro, the highest number for a Zona da Mata site was 71 species at Refúgio Ecológico Charles Darwin.

Repetitive sampling at RPPN Fazenda São Pedro showed a strongly increasing number of recovered species with the second and third visit (Fig. 4). The first and second visit yielded 53 and 58 species, respectively, with the second visit adding 33 species to the list, that is 57% novelties. The third visit resulted in 26 species, 13 of which or 50% being further new additions to the list and raising the total number to 99. The two additional visits thus almost doubled the original number of 53 species for the first visit. Both the second and third visit had a higher precentage of rare, inconspicuous, sterile, and/or cryptic species, and this pattern was even more pronounced when taking into account only the new (extra) additions (Fig. 5), but the differences were not significant at the 5%-level (Chi-square test).

The average number of species per site for the 22 localities studied by opportunistic sampling (method I; including first visit to RPPN Fazenda São Pedro) was 30.5 or 30% of the total number found at the repetitively sampled RPPN Fazenda São Pedro (method II). Taking into consideration only the 11 Zona da Mata (including RPPN Fazenda São Pedro), the average number was slightly lower (28.5 species). The total number of species collected by opportunistic sampling (method I), within 22 localities, was 351, of which 50 were found in the Caatinga localities only and 301 also in the rainforest localities (Mata Atlantica, Brejos de Altitude). The total number of species at RPPN Fazenda São Pedro, combining repetitive and quantitative sampling (methods II and III) was 205. Thus, the combined sampling methods II and III for a single site yielded 68% of the number of species found by method I at 22 sites together. Of these 205 species, 44 were shared between methods II and III, while 55 were exclusive to method II and 106 exclusive to method III. Of the latter, 30 species were also found using method I within the 22 remaining localities, which means that among all the species, 76 were only found within the transect (method III).

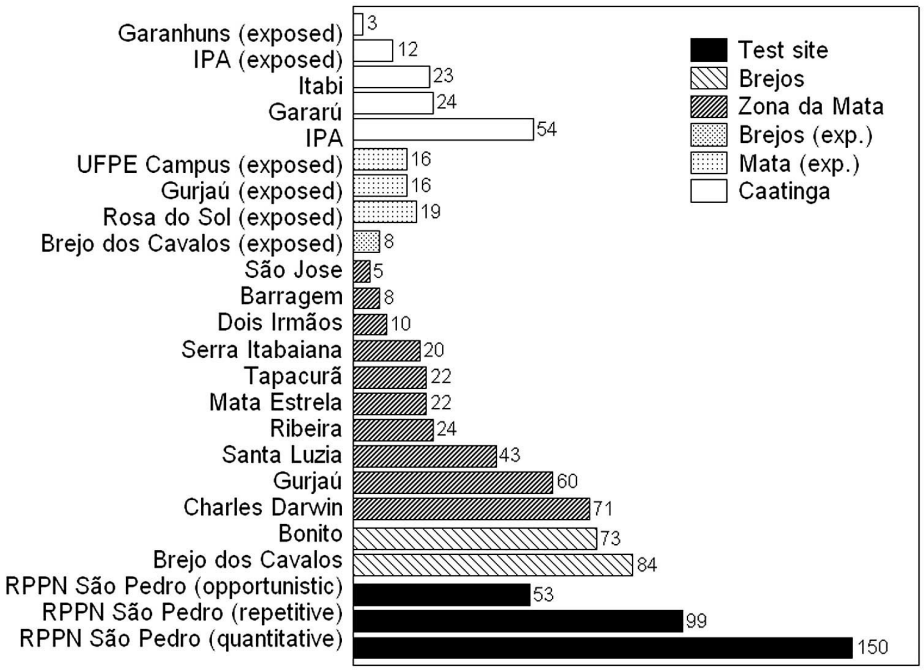

FIG. 3. Number of species of crustose and microfoliose lichens found at 22 localities in north-eastern Brazil, by means of non-quantitative opportunistic sampling (method I), compared to the number of species found at RPPN Fazenda São Pedro by means of repetitive non-quantitative opportunistic sampling (method II) and quantitative transect sampling (method III).

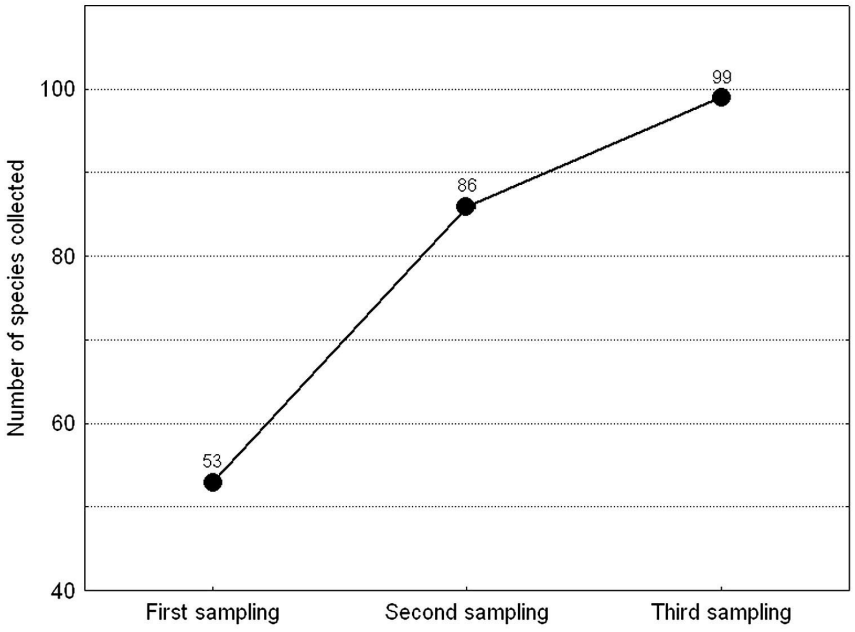

FIG. 4. Increase of the number of species with the second and third visit at RPPN Fazenda São Pedro (repetitive sampling with method II).

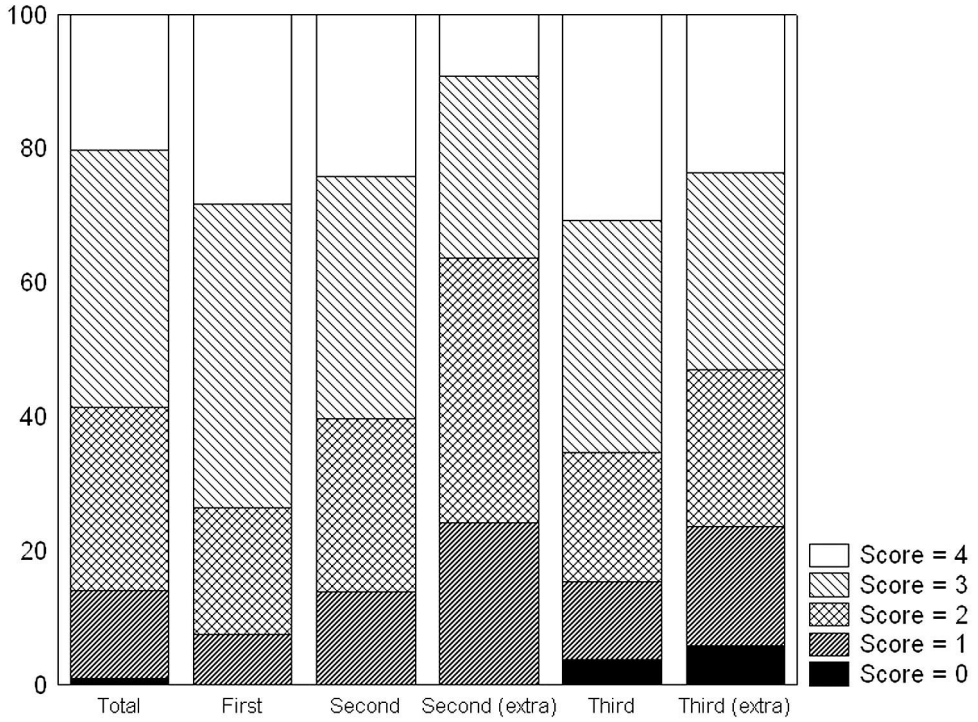

FIG. 5. Proportion of combined lichen parameter scores CS among the 99 lichen species collected at RPPN Fazenda São Pedro (repetitive sampling with method II), separated by visits (first, second, third) and also separating the extra collected species only during the second and third visit.

About 17% of the recorded species are thus unique to the transect at RPPN Fazenda São Pedro and were not found through opportunistic sampling (method I) within any of the other localities, being also absent from the collections made through repetitive sampling (method II) at RPPN Fazenda São Pedro. The total number of species found within the transect (150) was far higher than at any other locality, especially considering that the number of trees sampled within the transect (47) was lower. The number of lichen species per sampled phorophyte tree was by far highest within the transect (3.19) and much lower (0.39–0.66) in the localities sampled my methods I and III, whereas the number of lichen species per collected specimen was about the same (0.19–0.22) for sampling methods I and II and slightly higher (0.27) for method III (Table 5). If the five most frequent species (*Porina conspersa*, *Diorygma poitaei*, *Opegrapha* aff. *contracta*, *Dichosporidium nigrocinctum*, *Cryptothecia striata*) are excluded from the transect, the number of collected specimens is reduced by 140, and the remaining 145 species are distributed among 410 samples only, which gives a ratio of 0.35 species per specimen. Excluding the ten most frequent species, the ratio increases to 0.39 species per specimen, about twice the ratio found for methods I and II.

Most of the lichen species had combined lichen parameter scores ranging between CS = 1 and CS = 3 (100–156 species per score category), while species with combined scores CS = 0 and CS = 4 were much fewer in number (Fig. 6). The relative proportion of scores was not significantly different from the overall proportions for the Caatinga species and for categories D–F, while significicant differences were found for all other categories (Table 6). Thus, categories A–C (chiefly species found by opportunistic sampling) had significantly higher proportions of species with combined scores CS = 2, 3, and 4, while category G (species found by quantitative sampling) had significantly higher proportions of species with combined scores CS = 0 and 1. In other words,

the proportion of species which are abundant, conspicuous, fertile, and/or distinctive, is higher among those taxa found by opportunistic sampling, while the proportion of rare, inconspicuous, sterile, and/or cryptic species is higher among those taxa found by quantitative sampling. Among these are especially the sorediate species of *Malcolmiella* and Thelotremataceae, the isidiate and sterile species of *Cryptothecia* and *Herpothallon*, and several other unnamed species with sterile, sorediate or isidiate thalli, as well as the small, inconspicuous species of the genera *Bacidina*, *Coenogonium*, *Cryptolechia*, *Enterographa*, and *Fellhanera*. The overall proportion of species with combined scores CS = 0 or 1 for RPPN Fazenda São Pedro (collected by methods II and III) is 84 out of 205 or 41%, while the overall proportion for the 22 localities collected through opportunistic sampling (method I) is 56 out of 301 or 19% only.

TABLE 5. Number of lichen species collected and identified per sampling method relative to the number of sampled phorophyte trees and lichen specimens.

	Method I (all localities)	Method I (Zona da Mata only)	Method II (1 site)	Method III (1 transect)
Number of phorophytes	≈ 75 per site site	≈ 75 per site	≈ 150	47
Number of specimens	≈ 150 per site site	≈ 150 per site	≈ 450	≈ 550
Number of species	≈ 30	≈ 29	99	150
Species per phorophyte	0.40	0.39	0.66	3.19
Species per specimen	0.20	0.19	0.22	0.27

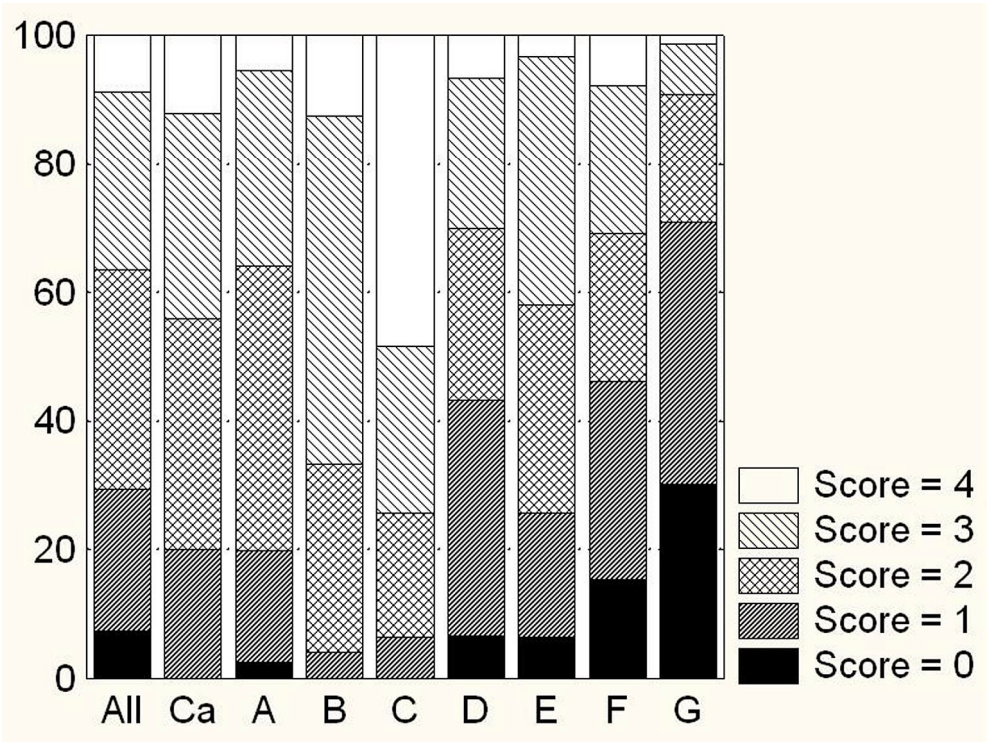

FIG. 5. Proportion of combined lichen parameter scores CS among all 456 collected and identified lichen species and among lichen species belonging to the seven categories A–G plus Caatinga.

TABLE 6. Results of observed vs. expected Chi-Square test to detect significant correlations between lichen distribution types and lichen detectability scores.

Distribution type	Combined score	Observed frequencies	Expected frequencies	Chi-Square value	p-level	Signifi-cance
Caatinga only (n = 50)	CS = 0	0	3.7	4.80	p = 0.3085	—
	CS = 1	10	11.0			
	CS = 2	18	17.1			
	CS = 3	16	13.8			
	CS = 4	6	4.4			
A: Other rainforest localities only ×–o–o (n = 201)	CS = 0	5	15.0	17.51	p = 0.0015	*
	CS = 1	35	44.1			
	CS = 2	89	68.7			
	CS = 3	61	55.5			
	CS = 4	11	17.6			
B: Other rainforest localities and site but not transect ×–×–o (n = 24)	CS = 0	0	1.8	11.92	p = 0.0180	*
	CS = 1	1	5.3			
	CS = 2	7	8.2			
	CS = 3	13	6.6			
	CS = 4	3	2.1			
C: Other rainforest localities, site and transect ×–×–× (n = 31)	CS = 0	0	2.3	63.20	p = 0.0000	***
	CS = 1	2	6.8			
	CS = 2	6	10.6			
	CS = 3	8	8.3			
	CS = 4	15	2.6			
D: Other rainforest localities and transect but not site ×–o–× (n = 30)	CS = 0	2	2.2	3.84	p = 0.4270	—
	CS = 1	11	6.6			
	CS = 2	8	10.3			
	CS = 3	7	8.3			
	CS = 4	2	2.6			
E: Site only but not transect o–×–o (n = 31)	CS = 0	2	2.3	2.63	p = 0.6201	—
	CS = 1	6	6.8			
	CS = 2	10	10.6			
	CS = 3	12	8.6			
	CS = 4	1	2.7			
F: Site and transect o–×–× (n = 13)	**CS = 0**	2	1.0	2.15	p = 0.7091	—
	CS = 1	4	2.9			
	CS = 2	3	4.4			
	CS = 3	3	3.6			
	CS = 4	1	1.1			
G: Transect only o–o–× (n = 76)	**CS = 0**	23	5.7	85.53	p = 0.0000	***
	CS = 1	31	16.7			
	CS = 2	15	26.0			
	CS = 3	6	21.0			
	CS = 4	1	6.7			

DISCUSSION

This analysis demonstrates that sampling technique is crucial to correctly estimate lichen species richness within a given area. On a raw scale, considering only localities with comparable ecological parameters, method I (non-quantitative opportunistic sampling) recovered only about one third the number of species on average than method II (repetitive non-quantitative opportunistic sampling). Method III (quantitative transect sampling) recovered more than five times the number of species than method I on average and 50% more species than method II.

Assuming that the studied localities are ecologically comparable and there are no intrinsic differences between the localities in terms of lichen species richness and spatial distribution of lichen species, the differences found in lichen species richness are chiefly due to the different sampling methods employed, and the two main differences between the three methods is the number of specimens collected and the spatial distribution of the collected specimens. This is especially obvious when comparing the number of species recovered from the same site, RPPN Fazenda São Pedro, by opportunistic (53), repetitive (99), and quantitative sampling (150). The relatively constant species per specimen ratio between methods I and II indicates a linear increase of the number of species with the number of specimens when switching from opportunistic to repetitive sampling. Method III, on the other hand, results in a higher species per specimen ratio, suggesting that sampling is more effective in terms of recovered species per amount of material. However, one disadvantage of that method is that frequent species are over collected, which results in a high amount of samples representing few frequent species only. Excluding the most frequent species from method III, the species per specimen ratio increases to almost twice the ratio found for methods I and II, thus increasing effectiveness in terms of recovery of species richness by almost 100%. This difference is explained by the fact that, with the quantitative transect method, one is forced to collect specimens that one would usually not collect by means of visible inspection only, because they are either rare, inconspicuous, sterile, and/or cryptic, a notion that is confirmed by the significantly higher proportion of such species with the quantitative transect method, while the non-quantitative opportunistic method recovers a higher proportion of abundant, conspicuous, fertile, and/or distinctive taxa.

Perhaps the most striking examples are the genera *Cryptothecia* and *Herpothallon*, whose species are frequently sterile and form white or pale green crusts that are easily seen but which do not usually call the attention of the opportunistic collector since they appear to belong to the same or few different species only and are not very promising candidates for successful identification. A large number of specimens of these two genera was collected within the transect, and microscopical and chemical examination revealed that the number of cryptic species was unusually high: what appeared as two different taxa in the field turned out to represent no less than nine different species after careful study in the laboratory. None of these species was collected using opportunistic sampling, although these taxa are certainly abundant outside the transect. Other examples include the genera *Bacidina*, *Coenogonium*, *Cryptolechia*, *Enterographa*, *Fellhanera*, *Ramonia*, and *Stictis*, which are unlikely to be collected by opportunistic sampling due to their small and inconspicuous thalli and fruit bodies, as well as the highly diverse but usually sterile, sorediate Thelotremataceae (Emmerer & Hafellner 2004). Species of *Coenogonium*, as well as *Graphis* and several pyrenocarpous genera (*Anisomeridium*), are known to contain a high number of cryptic species which cannot be identified in the field (Harris 1995, Rivas Plata *et al.* 2006, Lücking *et al.* 2007), and also in these genera, quantitative transect sampling is likely to turn out higher species numbers than opportunistic sampling.

The different sampling techniques available for biotic surveys in general are composed of two independent elements: (1) the size and nature of the samples, and (2) the spatial placement of the samples within the area in question. Non-quantitative sampling does not use sample quadrats or rectangles, but instead individual lichen thalli are collected from the substrate upon visual inspection. Quantitative sampling, on the other hand, works with sample quadrats or rectangles of a

given size, depending on the method employed, and there are three ways of spatial arrangement of sample quadrats or rectangles: (1) randomly, (2) subjectively within subplots representing different vegetation types, which corresponds to the relevé sampling method (Braun-Blanquet 1932), and (3) equidistant along a transect or grid. The last two approaches have also been combined into so-called stratified sampling (4), where different microhabitats (subplots) are identified and then sample quadrats or rectangles are placed randomly or equidistant within these plots (Newmaster 2003). The latter method proved most successful for adequately recovering bryophyte diversity, but while the success of that or other quantitative methods in recovering species richness is usually attributed to the combined random and systematic placement of samples, the present study suggests that actually the large number of 'forcedly' collected specimens, and their complete identification to species level, are the underlying causes for recovering higher species numbers.

The present study can also be used to estimate total lichen species richness for a given site. Based on the species numbers resulting from opportunistic sampling, RPPN Fazenda São Pedro can be considered a moderately diverse site, since it ranged third with 53 species (first visit only) after Charles Darwin (71 species) and Gurjaú (60 species), followed by Santa Luzia (43 species). This is supported by the fact that many lichen species detected in other Mata Atlantica remnants of the study area were not found at RPPN Fazenda São Pedro. The total number of species found at RPPN Fazenda São Pedro, however, combining all three sampling methods, was 205, roughly four times the number found by one-time opportunistic sampling. If the factor 4 is applied to the other sampled localities, the total number of species is estimated to ≈ 280–330 (4 × 71–84) for the three supposedly richest sites Charles Darwin, Bonito, and Brejo dos Cavalos. These numbers are identical to the rather well-supported estimates for sites in Costa Rica and Venezuela, with about 300 corticolous lichen species per site (Komposch & Hafellner 1999, 2000, 2002, Moncada *et al.*, in prep.; Lizano *et al.*, in prep.) and also show that the Atlantic rainforest in northeastern Brazil supports high lichen diversity inspite of its relatively dry conditions. It can then be assumed that the southeastern Atlantic rainforest in the states of Minas Gerais to Rio Grande do Sul supports even higher figures, which is consistent with the notion that this area is one of the regions with the highest organismic diversity in the world (Myers *et al*. 2000).

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